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FEEDING DAIRY COWS ON ALFALFA HAY ALONE¹

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INTRODUCTION

During the last few years investigators have given much thought and study to the dairyman's problem of obtaining better quality in roughage and of utilizing roughages to a greater extent in feeding dairy cattle. This increased attention has been brought about partly by the economic situation, which has emphasized the necessity of keeping costs of milk production at a low level; and partly by a growing realization that extremely high milk production per cow, obtained by heavy grain feeding, is not necessarily the most economical production.

The Bureau of Dairy Industry has long recognized the important advantages of growing and feeding roughage crops on the dairy farm, and for a number of years the dairy-cattle feeding investigations carried on at the Bureau's regional experiment stations have been concerned with various phases of the problem of including more and better

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roughage in the dairy ration. In its experiments (17, pp. 15-22)³ at the Huntley, Mont., station, for example, the Bureau has shown the relative production of cows when fed roughage exclusively, and when fed roughage with grain. Graves and Shepherd⁴ have shown the relative economy of milk production under different feeding systems when the crops (both grain and roughage) are home grown. The importance of cutting roughage crops (grasses and hays) at early stages of maturity in order to improve their nutritive value for milk production was shown in experiments with Sudan grass at the Woodward, Okla. station (4) and with pasture grasses at the Huntley station (7). Experiments are now under way to furnish information on other phases of roughage feeding.

In many irrigated sections of the United States alfalfa hay is grown in abundance, and is the crop, next to pasturage, in which nutrients for milk production can be produced at the lowest cost. In these regions dairy cows are fed rations consisting almost entirely of alfalfa hay. Apparently, this heavy feeding of alfalfa hay, year after year, has no detrimental effect on the animals' health. However, very few definitely controlled experiments have been conducted to show the comparative effects on milk production and on the condition of the cows, of feeding alfalfa hay alone for extended periods as compared with other systems of feeding.

Experiments by the Bureau have shown that cows will produce somewhat more milk when they have access to pasture during the pasture season and some other good roughage such as silage is added to the ration, than when they are restricted to alfalfa hay. Whether these other feeds add some nutritive element that is not present in alfalfa hay or whether they simply provide a greater variety in the ration, and thereby stimulate a greater consumption of feed which brings about this greater production, is not definitely known.

This bulletin gives the results of feeding 15 Holstein-Friesian cows throughout 26 lactation periods entirely on alfalfa hay. As a rule, alfalfa hay would not be fed exclusively throughout the year under commercial conditions. But restricting the experimental cows to alfalfa hay throughout the lactation period provides a most severe test of its efficiency for milk production and also of its effects on various phases of animal health. Feeding alfalfa hay alone also has an experimental advantage over feeding a ration in connection with pasturage, in that the amount of nutrients consumed can be measured more accurately.

The production of alfalfa has increased greatly in many sections in the last few years and will probably continue to increase for years to come. This is because alfalfa is not only a cheaper source of nutrients for milk production than most other crops produced where it grows abundantly, but is also a soil improver and has an important place in conservation of the land and in control of erosion.

The results of the experiment herein presented should be a useful

³ Italic numbers in parentheses refer to Literature Cited, p. 45.

⁴ GRAVES, R. R., and SHEPHERD, J. B. A STUDY OF CERTAIN PHASES OF THE ECONOMICS OF DAIRY-CATTLE FEEDING. U. S. Bur. Dairy Indus., Roughage Feeding Ser. 1, BDIM-625, 1933. [Mimeographed.]

UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF DAIRY INDUSTRY. ROUGHAGE RATIONS FOR DAIRY COWS MAKE LESS MILK AND MORE PROFIT. U. S. Bur. Dairy Indus., Roughage Feeding Ser. 2, BDIM-626, 1934. [Mimeographed.]

GRAVES, R. R., and SHEPHERD, J. B. A STUDY OF THE EFFECT OF MODIFIED SYSTEMS OF FARMING ON MILK PRODUCTION AND NET RETURNS OVER CASH OUTGO FOR PURCHASED FEEDS. U. S. Bur. Dairy Indus., Roughage Feeding Ser. 3, BDIM-627, 1934. [Mimeographed.]

contribution to our knowledge concerning one phase of the feeding of dairy cows that has heretofore received very little attention, and also of the efficiency of alfalfa hay for milk production.

REVIEW OF THE LITERATURE

The literature is rather extensive concerning experiments in which alfalfa hay has been fed as a part of various rations for dairy cattle. This review is confined to the comparatively few investigations wherein alfalfa hay, with or without mineral supplements, was the only feed used over periods long enough to bring out the advantages or disadvantages of such a system of feeding, as indicated by its effects on the animals and on the economy of milk production.

Reed, Fitch, and Cave at the Kansas Agricultural Experiment Station (19) fed a group of six Holstein heifers on alfalfa hay exclusively from the age of 6 months through their first and second 10-month lactations. For the two lactations they averaged 4,124 pounds of milk and 150 pounds of butterfat, or an average of 1 pound of milk for each 2.24 pounds of alfalfa hay consumed and 1 pound of butterfat for each 61.6 pounds of hay consumed. Two of these heifers were later carried through a third lactation period under full-feed conditions, in which they received grain and silage and pasture in addition to alfalfa hay. On the full-feed ration the two heifers averaged 8,191 pounds of milk containing 298 pounds of butterfat. Both heifers increased very materially in body weight.

Two additional groups of heifers that were fed hay, grain, silage, and pasture produced approximately 40 percent more milk and butterfat during the first lactation than the group receiving alfalfa hay alone.

The breeding records revealed that there was slightly less difficulty in bringing about conception in the animals fed exclusively on alfalfa hay than in those fed on hay, grain, and silage.

Woll (20) at the California Agricultural Experiment Station fed three heifers (one Holstein and two Jerseys) through two lactations on alfalfa hay and green alfalfa. They consumed 1.7 pounds of alfalfa-hay equivalent for each 1 pound of milk produced in the first lactation, and 1.6 pounds of hay equivalent in the second lactation. The hay consumption per pound of milk was somewhat lower than that reported by the Kansas station. There was no evidence that the exclusive feeding of alfalfa affected the breeding or fertility of the cows.

A later report by Woll and Voorhies (1), comparing production on alfalfa hay with that on a mixed ration that included full-grain feeding, gave the following summary: The average production on the alfalfa ration was 6,491.5 pounds of milk and 258.86 of butterfat, and on mixed ration, 7,336.8 pounds of milk and 323.37 of butterfat. The animals on the alfalfa ration produced 88.4 percent as much milk and 80.0 percent as much butterfat as those on the mixed ration that included full-grain feeding.

Headley (12) of the Nevada Experiment Station fed four grade Holstein cows for 4 years on selected alfalfa hay alone. They averaged 8,644 pounds of milk containing 304 pounds of butterfat per cow per year, and consumed 1.6 pounds of hay for each pound of milk produced. Their body weights remained practically stationary, averaging 1,355 pounds per cow per year. Four similar grade Holstein cows that were

allowed selected alfalfa hay at will were fed an average of 2,160 pounds of grain in addition, which was approximately at the rate of 1 pound to each 5 pounds of milk produced. Their production for the 4 years averaged 10,352 pounds of milk and 359 pounds of butterfat per cow per year. The cows on alfalfa hay alone produced 83 percent as much milk and a little less than 85 percent as much butterfat as the cows that were fed alfalfa hay and grain. The grain feeding apparently had little effect on the amount of hay consumed. A third group of cows fed the alfalfa hay ration and the grain and hay ration in alternating years averaged 9,163 pounds of milk and 326 pounds of butterfat. Their average hay consumption was only slightly less than that of the first group. Their body weights increased, especially during the years when grain was fed. There was some indication that the cows fed continuously on alfalfa hay alone were more inclined to breeding trouble, but the small number of animals does not warrant definite conclusions.

In comparing the feeding value of alfalfa hay produced in central Oregon and in the Willamette Valley, the Oregon Agricultural Experiment Station (18) fed two groups of three cows each on alfalfa hay exclusively for 342 days. Little difference was found in the two hays. The six cows consumed an average of only 9,936 pounds of hay during this period or less than 30 pounds per cow per day. Their production was very low, however, averaging only 3,953 pounds of milk containing 148 pounds of butterfat. It was stated that—

this compares very unfavorably with the production of 300 to 450 pounds of butterfat per year claimed by many dairymen feeding only alfalfa hay. This discrepancy can hardly be due to better cows, as several of the cows used in the test have demonstrated their ability.

Later, in referring to the same experiment, Haag and coauthors (11) state that "the milk production of the animals restricted to alfalfa hay was approximately one-half that to be expected on the regular herd ration." They concluded that the intake of total digestible nutrients was not adequate for more than very moderate milk production. The body weights of the cows were not given. If the Savage standard of total digestible nutrients required for a body weight of 1,000 pounds is used, the consumption of 9,936 pounds of alfalfa hay of average nutrient content, would be enough for maintenance and the production of approximately 7,300 pounds of milk testing 3.7 percent of fat and containing 270 pounds of butterfat. This, however, is 3,346 pounds more milk than they actually produced.

Metabolism studies with some of the above-mentioned cows on alfalfa hay alone showed that early in the lactation period the cows were usually in positive calcium balance and were always in negative phosphorus balance. Feeding disodium phosphate changed the negative phosphorus balances to slightly positive balances. The hay contained 1.6 percent of calcium and 0.153 percent of phosphorus. A later report by Haag and others (10) showed that cows on alfalfa hay alone gave negative calcium and phosphorus balances and that the supplemental feeding of bonemeal resulted in distinctly positive calcium and phosphorus balances. They point out, however, in a general review of their work that the rapid decline in milk flow of cows fed largely on alfalfa hay is suggestive of a lack of specific nutrients rather than of total digestible nutrients. They question the biological

value of the proteins of alfalfa hay (when fed alone), especially the lack of the amino acid cystine as reported by Haag (9) in work with rats. A preliminary feeding trial indicated that wheat bran, a fairly good source of cystine, was effective as a supplement to alfalfa hay for dairy cows.

Huffman and coworkers (14, 15) at the Michigan Agricultural Experiment Station and Eckles and coworkers (5) at the Minnesota Agricultural Experiment Station have published results that apply to certain phases of this experiment. Their publications also include a complete review of the literature covering phosphorus deficiencies and requirements of dairy cattle.

Some investigators have reported undesirable effects on the milk (and its byproducts) produced by cows fed exclusively on alfalfa hay. Richardson and Abbott (3) at the California station found indications that from 6 to 8 weeks on straight alfalfa feed caused cows to produce butterfat that made up into a typical sticky butter. Adding silage to the ration removed this condition, but it required about the same length of time for the butterfat to become normal.

Roadhouse, Regan, and Mead (2) of the same station showed that alfalfa in the form of hay or pasture, or when cut and fed in the green form, produced a marked flavor in the milk if fed within 5 hours before milking. The hay produced the least noticeable flavor.

EXPERIMENTAL PROCEDURE

EXTENT OF THE DATA AND HISTORY OF COWS USED

The Bureau of Dairy Industry maintains seven field experiment stations, located in as many different regions, for the purpose of conducting breeding and feeding experiments of regional and National interest and importance. The data for the study reported herein are from the results of work at the stations at Mandan, N. Dak., Huntley, Mont., Woodward, Okla., and Ardmore, S. Dak.⁵

The breeding experiments at these stations require that all females be raised to producing age under similar environmental conditions, and tested under full-feed conditions to determine their inherited capacity for milk and butterfat production. After completing these tests, the cows are available for use in various other feeding experiments.

Since all cows are raised, handled, and tested under similar conditions at all stations, comparable production records under full-feed conditions are normally available. But comparable records to show the relative level of production by the same cows when they are fed other rations must be obtained by further feeding experiments.

For the purpose of this study, 15 registered Holstein-Friesian cows that had completed 365-day production records under full-feed conditions were subsequently fed for yearly lactation records on a ration restricted to alfalfa hay. Table 1 gives the herd number, the previous history and breeding record, and the age of each of these cows at the time they were entered in the alfalfa hay feeding experiment, as well as their breeding records during their two or three consecutive lactations on the alfalfa hay rations.

⁵ Dairy work at the Ardmore, S. Dak., station was discontinued in 1932.

TABLE 1.—*History and breeding records of the 15 Holstein-Friesian cows for the period before they were fed the alfalfa hay ration, and observations during the experiment by lactation periods*

Cow No.	Age at start of experiment		History before use in experiment on alfalfa hay alone	History by consecutive lactations on alfalfa hay ration		
	Years	Months		First lactation	Second lactation	Third lactation
H-31	7	4	Had 2 lactations on limited grain, 1 on roughage alone, and 1 on full feed. Perfect breeding record.	Normal in all respects	Normal in all respects	
H-38	5	8	Had 1 lactation on full feed, 1 lactation on limited grain. Some breeding trouble.	Did not come in oestrus during lactation. Developed vaginitis. Conceived later after treatment.	Breeding normal, but was bred too soon; record for 285 days. Appetite better. Milk developed a lila flavor and odor.	
H-39	6	9	Breeding trouble. Inbred.	Breeding normal. Rather poor appetite for hay.	Breeding normal. Calved normally. Calf weak.	
H-52	6	4	Breeding trouble. Aborted twin fetuses, 1 abnormal presentation.	Breeding trouble. Abnormal calf. Abnormal flavor and odor in milk for a short period.	Normal in all respects	
H-53	6	3	Breeding normal. 1 dead calf. 1 abortion.	Normal in all respects		
H-62	3	11	Normal in all respects	Developed vaginitis. Bred once, did not conceive or later come in oestrus. Sold as nonbreeder.		
H-64	4	10	do	Breeding normal. Bred too soon. Record for 308 days.	Accidentally bred at first heat period. Record for 265 days.	Bred 4 times before calving. Aborted.
W-21	7	11	do	In oestrus at all times; did not conceive. Sold as nonbreeder upon completion of record.		
W-44	3	9	Normal breeding record. Aborted first calf. Inbred.	Normal breeding record. Heavy consumption of hay with high refusal.	Normal breeding record. Went dry in 285 days.	Normal in all respects.
W-47	3	9	Normal breeding record	Normal breeding record. Aborted a decomposed fetus that was carried 199 days. Low production.	Normal breeding record. Dry for 16 months previous to this lactation. Low production.	
W-54	4	4	Normal in all respects.	Normal in all respects	Did not show signs of oestrus until 6 months after calving.	
W-55	3	8	do	Normal breeding record. Poor producer.		
W-63	3	7	Bred 4 times for first calf. Some mastitis.	Normal in all respects	Normal in all respects	
W-69	3	5	Normal in all respects.	do		
270	9	4	Some breeding trouble as a younger cow. Extremely high producer. Raised at Reitsville, Md., shipped to Mandan, N. Dak., few months previous to start of experiment.	do		

TABLE 2.—Production records of the 15 Holstein cows when fed the alfalfa hay ration and when on full feed

Cow No.	When fed the alfalfa hay ration						When on full feed					
	Alfalfa hay consumed	Age		Period carrying calf	Milk	Butterfat	Calculated to maturity		Milk	Butterfat	Calculated to maturity	
		Year	Month				Milk	Butterfat			Milk	Butterfat
H-31	Pounds 10, 134	7	4	248	Pounds 12, 225	Pounds 426.8	Pounds 12, 225	Pounds 426.8	Days 224	Pounds 16, 677	Pounds 559.5	Pounds 559.5
H-31	16, 304	8	5	211	11, 735	411.5	11, 735	411.5				
H-38	16, 204	8	8	169	14, 300	386.4	14, 300	386.4				
H-39	12, 552	9	9	169	10, 819	298.9	10, 819	298.9	0	15, 067	501.0	506.2
H-39	15, 691	8	1	251	7, 539	209.0	7, 539	209.0	10	11, 587	441.8	547.8
H-52	15, 901	8	4	241	12, 557	468.9	12, 557	468.9				
H-52	14, 984	8	1	241	10, 892	402.9	10, 892	402.9	6	15, 396	530.7	684.6
H-53	16, 367	7	3	186	12, 359	509.9	12, 359	509.9				
H-53	17, 199	7	6	197	10, 729	396.9	10, 729	396.9	6	13, 940	522.5	674.0
H-62	11, 954	3	11	0	9, 966	335.8	9, 966	335.8	6	16, 071	529.9	683.6
H-64	11, 794	4	10	246	10, 294	370.9	10, 294	370.9	2	15, 215	522.0	668.2
H-64	11, 530	5	10	229	7, 108	290.3	7, 108	290.3				
H-64	11, 826	6	8	40	9, 978	375.5	9, 978	375.5				
H-21	17, 092	7	11	0	15, 109	487.5	15, 109	487.5	5	15, 908	499.9	654.9
W-44	16, 278	3	9	206	401.5	12, 967	401.5	12, 967	6	12, 520	430.3	555.1
W-44	12, 155	4	11	199	7, 641	253.6	7, 641	253.6				
W-44	14, 237	6	2	189	7, 876	278.8	7, 876	278.8				
W-47	13, 533	3	9	183	8, 603	254.7	8, 603	254.7	7	11, 893	348.6	522.9
W-47	11, 085	6	1	245	8, 181	254.1	8, 181	254.1				
W-54	13, 164	4	4	205	9, 427	317.6	9, 427	317.6	2	17, 110	548.7	746.2
W-55	13, 094	3	8	219	8, 285	258.2	8, 285	258.2	5	17, 947	563.5	738.2
W-55	16, 466	4	10	155	12, 783	391.0	12, 783	391.0				
W-63	13, 638	3	3	39	11, 013	380.4	11, 013	380.4	3	12, 719	444.6	600.2
W-69	13, 386	3	5	259	9, 936	326.6	9, 936	326.6	2	17, 739	523.2	722.0
270	14, 089	9	4	208	11, 210	437.5	11, 210	437.5	1	21, 763	800.5	908.5
270	15, 158	10	4	188	9, 713	389.4	9, 713	389.4	9			
Average ⁶	14, 352	5	11	164	10, 702	375.6	11, 125	389.6	183	15, 376	517.8	651.5

¹ Milked twice a day on the alfalfa hay ration; 3 times a day on full feed.² Bred too soon, milked for 288 days on the alfalfa hay ration; this record on hay was not used in the average.³ Bred too soon, milked for 288 days on the alfalfa hay ration.⁴ Bred too soon, milked for 285 days on the alfalfa hay ration; this record on hay was not used in the average.⁵ Record on the alfalfa hay ration; 285 days when cow went dry.⁶ Average for 24 records on the hay ration; 15 records on full feed.

At the Mandan station, cow H-64 completed three consecutive lactations on the alfalfa hay ration and cow 270 completed two. At the Huntley station, cows H-31, H-52, and H-53 each completed two consecutive lactations, and H-38 and H-62 each completed one lactation. At the Ardmore station, H-39 completed two consecutive lactations. At the Woodward station, W-44 completed three consecutive lactations, W-47 and W-55 two each, and W-21, W-54, W-63, and W-69 one lactation each.

The 15 cows completed a total of 26 lactation records on the alfalfa hay ration. All but 4 of the 26 records were for 365 days. Two of the records (second records of H-39 and H-64) were for less than 300 days, because the cows were accidentally bred too soon after calving, and are omitted from the calculations because they are not comparable. On the other hand, two other records, one for a little more and one for a little less than 300 days, were considered comparable with the 365-day records and are included in the calculations.

Table 2 gives the production records of the 15 cows for their 26 lactation periods on the alfalfa hay ration, also their production records for their 15 lactation periods on the full-feed ration.

All the records on full feed with the exception of cow 270 were made in stanchions, and the cows were milked three times a day. Grain was fed at the rate of approximately 1 pound to each 3 pounds of milk produced, and the roughage part of the ration consisted of alfalfa hay, silage, and pasture.

Although the feeding and management conditions under which the full-feed records were made were not extreme, they were such as to enable these cows to produce somewhere near their inherent capacity. As will be shown later in the discussion of the feed and nutrient consumption, all these cows were capable of a high level of production under good feeding conditions.

Nearly all the cows made their full-feed records at an immature age, but they varied considerably in age when they were on the alfalfa hay ration. Because of such variations, and also because of the fact that some of the cows had been accustomed to roughage for long periods, it is necessary to present and discuss the results in more detail than if all the cows had been equal in age and production and had been accustomed to a ration of roughage only.

FEEDING THE ALFALFA HAY RATION

The cows were not all on the alfalfa hay ration simultaneously. Individual cows were started on the ration, independently of other cows, whenever they were available and always at a time when they could complete the entire lactation period on alfalfa hay. Each cow was started on the alfalfa hay ration at approximately 30 days before calving in order that she would be accustomed to the ration when her lactation began. After a cow had once started on the alfalfa hay experiment, she was fed alfalfa hay exclusively, throughout the entire lactation period and the dry period, until she was taken off the experiment. Of the 15 cows, 7 were on the experiment for 2 consecutive lactations, and 2 for 3 consecutive lactations.

At Woodward, Ardmore, and Huntley, the cows were kept in stanchions while the hay was being fed. When the weather was favorable they were turned into an exercising lot where no feed was available. The hay was weighed out to the cows twice a day, and the amount not

eaten was weighed back once a day. Cows W-54, W-63, and W-69 at the Woodward station were carried as a group for part of their lactation and the hay consumed and refused was prorated. At the Mandan station, cows H-64 and 270 were kept in a pen barn, each cow being kept in a small pen in order to obtain individual hay-consumption records. All cows either had frequent access to water in the lots or drinking cups were provided in the stanchions.

After the cows became well accustomed to the hay ration, an attempt was made to offer them approximately 10 percent more hay than they were consuming. It was found, however, that when the amount offered was restricted too closely the amount they would consume was lessened. The average amount rejected varied widely for different cows. One of the cows consumed as high as 93.4 percent of the amount offered over the year and one consumed only 65.4 percent (table 9). However, the wide variations in percentage consumed by the different cows was probably due more to the palatability of the hay and to the individual preferences of the cows, than to the amount offered in excess of what they would eat. The average consumption for all cows was 84.7 percent of the amount offered. It was noted with the majority of the cows that the refused hay was not confined entirely to the coarse stems. A portion of the weigh-back consisted of shattered leaves.

QUALITY OF ALFALFA HAY FED

The alfalfa hay used in these feeding experiments was produced in several different regions and varied in quality. The majority of the hay fed at Ardmore was produced locally under dry-land conditions, although some was purchased in northern Nebraska. All the hay fed at Huntley was produced locally under irrigation and was field cured, for the most part under good conditions. It was of excellent quality. Most of the hay fed at Woodward was produced locally under dry-land conditions and was of good quality and color; one year some of it was purchased near Garden City, Kans., and was of high quality. Most of the hay fed at Mandan, was purchased in the vicinity of Huntley, although a small amount of locally grown hay was fed which was also of good quality.

No attempt was made to select the hay for any of the animals; it was fed as it came. It was the practice, however, to purchase only good-quality hay. Although poor-quality hay was fed occasionally for short periods the majority of the hay would have graded U. S. No. 1 alfalfa. Samples were taken occasionally and sent to Beltsville, Md., for chemical analysis. A total of 34 samples were analyzed, consisting of 4 from Ardmore, 16 from Huntley, 8 from Woodward, and 6 from Mandan (table 11).

MINERAL SUPPLEMENTS FED

All cows had access to salt at will while they were on the alfalfa hay ration. In addition, a box containing special steamed bonemeal was so placed that each cow had access to it. It was observed that most of the cows ate little if any of the bonemeal. The amount consumed was measured for a time, but the consumption proved so small that measuring was discontinued. This is discussed more fully under Consumption of Calcium and Phosphorus.

MANAGEMENT OF COWS

All cows were milked three times a day, both when making their records on the alfalfa hay ration and under full-feed conditions, except cows H-39 and H-52, which were milked twice a day throughout the first lactation period on the alfalfa hay ration.

It was planned to have all the cows in milk for 365 days with a dry period of a month or 6 weeks between lactations. Unfortunately, some of the cows were accidentally bred too soon, and calved again in less than 300 days. Their records are included, but in some cases they are not used for comparisons.

RECORDS KEPT

Daily milk weights were kept, and once each month a sample of the milk was tested for butterfat. Daily weights were kept of the amount of hay fed and weighed back. The difference was considered as having been consumed. Body weights were taken for 3 consecutive days each month. The average monthly weight was calculated by averaging the weights for 2 consecutive months. The average lactation-period weights are the average of the weights for the first and last month in lactation. Some of the cows were weighed a day or two previous to and immediately following calving. For the others the nearest 3-day average weight previous to calving or following calving was considered as the precalving or after-calving weight.

Routine breeding and calving data were recorded at all times. Complete data were also available for all cows when under full-feed conditions. In addition, the men in charge of the cows noted any abnormal conditions they thought might be due to an exclusive ration of alfalfa hay. These observations will be referred to as the discussion of the data proceeds.

PRODUCTION OF MILK AND BUTTERFAT

PRODUCTION ON ALFALFA HAY ALONE

The individual records of milk and butterfat production on the alfalfa hay ration by lactation periods, the ages at which the records were made, the number of days each cow carried a calf, and the records calculated to a mature basis are given in table 2. Similar records for the same cows under full-feed conditions are included for comparison, and are discussed in subsequent sections. The individual amounts of alfalfa hay consumed are also included in table 2, but are discussed in a later section on Feed and Nutrient Consumption. The production records are for 365 days, unless otherwise noted.

The second record made by cow H-39 on the alfalfa hay ration is not comparable because she was accidentally served by a young bull, and since the exact breeding date was not known, it was considered advisable to dry her off at the end of 285 days. It should be mentioned, however, that during the first 255 days, before drying-off was started, she produced 7,338 pounds of milk and 292 pounds of butterfat, as compared with 8,320 pounds of milk and 313 pounds of butterfat during the first 255 days of her first lactation on the alfalfa hay ration, although she conceived 34 days after freshening for the

second record, whereas she conceived 191 days after freshening for the first record. She also consumed more hay during the 255-day period in the second lactation than in the first lactation. She was milked only twice a day for her first lactation record, however, and three times a day for her second.

Cow H-64 was bred too soon after freshening for both her first and second lactation on the alfalfa hay ration. During the first lactation, she was bred 62 days after calving and it was necessary to dry her off at the end of 308 days, when she was still producing 16 pounds of milk a day. She calved again in 30 days. During the second lactation, she was accidentally bred 34 days after calving, and it was considered advisable to dry her off at the end of 265 days, when she was still producing 15 pounds of milk a day. She calved again in 51 days. This latter record is not included in the calculations because of its short duration.

Cow W-44, in making her second lactation record on the alfalfa hay ration, went dry in 285 days. This record is included in the calculations.

Although H-39 and H-52 were milked twice a day for their first lactation records on the alfalfa hay ration and three times a day for their second records, no correction has been made for this difference in number of milkings, with one exception noted on page 14. In the case of H-52, the record made on twice-a-day milking materially exceeds the later record made on three-times-a-day milking. However, the lactation in which she was milked twice a day followed a rather short and low-producing lactation following an abortion. Furthermore, as she was an uncertain breeder and had to be bred five times for a conception, she did not carry a calf in the lactation period when she was milked twice a day, whereas she carried a calf for 241 days during the lactation when she was milked three times a day.

Cows H-38, H-62, and W-21 also exhibited breeding troubles and did not carry calves during their lactation period on the alfalfa hay ration, as shown in table 2. H-38 failed to come in oestrus, H-62 developed vaginitis, and W-21 was in oestrus at all times. These breeding troubles are discussed later from the standpoint of possible relationship to exclusive alfalfa hay feeding. They are mentioned here because of the effect of the number of days between freshening and conception, or conversely, the number of days they carried calves, on production.

It is evident that the period before conception, or the number of days the calf was carried, did have a decided effect on production, when the records are compared from this standpoint. There were six comparable records made by cows that conceived on an average of 351 days after freshening and that carried a calf 40 days or less during a lactation period on the alfalfa hay ration. The 6 records averaged 2,020 pounds more in milk and 55 pounds more in butterfat than 18 records made by cows that conceived, on an average, within 145 days after freshening and that carried a calf more than 100 days. The 4 records made by nonpregnant cows (table 2) averaged 2,642 pounds more milk and 79 pounds more butterfat than the 20 records made by cows that conceived on an average of 163 days after freshening and that carried calves an average of 197 days. This is a 25-percent greater production in milk and 21-percent greater production in butterfat for the nonpregnant cows.

The 24 comparable lactation records on the alfalfa hay ration averaged 10,702 pounds of milk and 375.6 pounds of butterfat (actual basis) and were made at the average age of 5 years 11 months. A few cows made their records at immature ages, and when these are calculated to a mature basis the 24 records average 11,125 pounds of milk and 389.6 pounds of butterfat. It should also be noted that the 2 yearly records of cow 270 on alfalfa hay were undoubtedly affected by her advanced age. This cow was raised at Beltsville and sent to Mandan as a mature cow. She had the highest production record on full feed of any cow in the experiment. It was made in a box stall at the Beltsville station. When she was placed on the alfalfa hay ration, at 9 years 4 months of age, she was showing the effects of age to a marked degree, but otherwise appeared to be in good condition and completed 2 full-time yearly records on hay.

The highest comparable milk record made on the alfalfa hay ration was 15,109 pounds in 365 days, and the lowest was 7,641 pounds for a 285-day lactation period. The cow making the highest record consumed 17,092 pounds of hay and produced 1 pound of milk for each 1.13 pounds of hay consumed. The cow making the lowest record (W-44, second record) produced 1 pound of milk for each 1.59 pounds of hay consumed. Fourteen of the twenty-four milk records are above 10,000 pounds. The highest butterfat record is 509.9 pounds (H-53, first record) which is approximately twice as much as the lowest butterfat record (W-47, second record).

COMPARISON BY CONSECUTIVE LACTATIONS

Table 3 was prepared to show the comparative production by nine cows that were on the alfalfa hay ration for two or more consecutive lactation periods. The number of days elapsing between freshening and conception is included because of its apparent effect on production.

TABLE 3.—Comparative milk and butterfat production and number of days between freshening and conception for cows fed the alfalfa hay ration for two or more consecutive lactation periods

Cow No.	First lactation			Second lactation			Third lactation		
	Milk	Butterfat	Days between freshening and conception	Milk	Butterfat	Days between freshening and conception	Milk	Butterfat	Days between freshening and conception
	Pounds	Pounds	Days	Pounds	Pounds	Days	Pounds	Pounds	Days
H-31.....	12,225	426.8	117	11,735	411.5	154	-----	-----	-----
H-39.....	¹ 10,319	¹ 386.9	196	² 7,527	³ 299.6	34	-----	-----	-----
H-52.....	¹ 12,557	¹ 468.9	365	10,892	402.9	124	-----	-----	-----
H-53.....	12,359	509.9	179	10,729	396.9	168	-----	-----	-----
H-64.....	³ 10,294	³ 370.9	62	⁴ 7,108	⁴ 260.3	34	9,978	375.5	325
W-44.....	11,578	401.5	159	7,641	⁵ 253.6	161	7,876	278.8	126
W-47.....	8,603	264.7	139	8,181	254.1	120	-----	-----	-----
W-55.....	8,285	258.2	146	12,783	391.0	210	-----	-----	-----
270.....	11,210	437.5	97	9,713	389.4	177	-----	-----	-----
Average of 7.....	10,974	395.4	171	10,239	357.0	159	-----	-----	-----

¹ Milked twice a day.

² Bred too soon; milked for 285 days; records not used in averages.

³ Bred too soon; record for 308 days.

⁴ Bred too soon; milked for 265 days; records not used in averages.

⁵ Record for 285 days; cow went dry.

One cow (W-55) on the alfalfa hay ration for two consecutive 365-day lactations produced 4,498 pounds more milk and 133 pounds more butterfat in the second lactation than in the first. She carried a calf only 155 days in the second lactation, however, and 219 days in the first, which may account in part for the higher production in the second lactation.

The records of cows H-39 and H-64 are omitted from the average because of abnormal factors other than feed. The other seven cows averaged 10,974 pounds of milk and 395.4 pounds of butterfat in the first lactation with an average of 171 days between freshening and conception, compared with 10,239 pounds of milk and 357.0 pounds of butterfat in the second lactation, with an average of 159 days between freshening and conception. The average production for the second consecutive lactation on the alfalfa ration was 10 percent less in butterfat and 6.6 percent less in milk than that for the first lactation.

The third consecutive lactation records made by the two cows (H-64 and W-44) are not comparable with their first and second records. The fact that both cows had a short second lactation may be partly responsible for the increased production during the third lactation, though there are many other factors than variations in the ration that may be responsible for differences in amount of production from lactation to lactation.

COMPARATIVE PRODUCTION ON ALFALFA HAY ALONE AND ON FULL FEED

The individual milk and butterfat production records made by the 15 cows, both under full-feed conditions and on the alfalfa hay ration, are shown in table 2. Since all the records on full feed except two (H-31 and 270) were made at immature ages, it was necessary to calculate them to a mature basis in order to afford a fair comparison with the records on alfalfa hay. The correction factors used were those published by Fohrman (6). The average production (mature basis) on full feed was 19,421 pounds of milk and 651.5 pounds of butterfat per cow. This is an increase of 8,296 pounds of milk and 261.9 pounds of butterfat, as compared with the average production (mature basis) for the 24 comparable records made on the alfalfa hay ration. The average production (mature basis) on the alfalfa hay ration was 57 percent as much in milk and 60 percent as much in butterfat as the average under full-feed conditions. If the actual records are used as a basis for comparison, the average production on the alfalfa hay ration was 70 percent as much in milk and 73 percent as much in butterfat as the average under full-feed conditions.

The 15 cows carried their calves for an average of 164 days per lactation when making the 24 records on the alfalfa hay ration, and for an average of 183 days under full-feed conditions. Any difference in this respect would be in favor of the records made under full-feed conditions.

The 20 records (mature basis) made by the cows that became pregnant during lactations on the alfalfa hay ration averaged 10,685 pounds of milk and 376.5 pounds of butterfat, and they carried calves for an average of 197 days. The 12 records made by the same cows under full-feed conditions (mature basis), when they carried calves for an average of 189 days, averaged 19,282 pounds of milk and 652.3 pounds of butterfat. On this basis of comparison, the average production

on the alfalfa hay ration was 55 percent as much milk and 58 percent as much butterfat as the average under full-feed conditions.

By comparing the records of those cows that conceived within a period of 30 days of each other in each group following calving, it is found that 11 records made on the alfalfa hay ration averaged 10,707 pounds of milk and 373.8 pounds of butterfat, with an average period of 155 days between freshening and conception. (In this case the first record of cow H-39, when she was milked twice a day, was increased by 20 percent so that it would conform to a three-times-a-day basis.) Seven records made on full feed by the same cows averaged 18,543 pounds of milk and 620.5 pounds of butterfat, with an average period of 162 days between freshening and conception. On this basis of comparison, the average production on the alfalfa hay ration was 58 percent as much milk and 60 percent as much butterfat as the average under full-feed conditions. The average percentage by months in lactation for these two groups is discussed on page 17.

Another point of interest in considering the two systems of feeding is the higher ratio of production on alfalfa hay at the Huntley station as compared with the records made at the Ardmore, Mandan, and Woodward stations. Cows H-31, H-38, H-52, H-53, and H-62 made their records at the Huntley station. Their eight records on the alfalfa hay ration (mature basis) averaged 12,017 pounds of milk and 435.1 pounds of butterfat, and they carried their calves for an average of 135 days. Their five records made under full-feed conditions averaged 18,697 pounds of milk and 641.6 pounds of butterfat (mature basis) and the average number of days each carried a calf was 172. These records indicate that they produced 64.3 percent as much milk and 67.8 percent as much butterfat on the alfalfa hay ration as on the full-feed ration. However, cows H-38, H-52 (first record), and H-62 were not pregnant during their lactations on the alfalfa hay ration. On eliminating these three records and the full-feed records of H-38 and H-62, comparison of the five records of H-31, H-52, and H-53 on the alfalfa hay ration (when they carried calves for an average period of 216 days) with their three records on full feed (when they carried calves for 200 days) shows that they produced 64 percent as much milk and 67 percent as much butterfat on alfalfa hay as they produced under full-feed conditions.

The records made on the alfalfa hay ration at the Mandan station are those for cows H-64 and 270. The first lactation on the alfalfa hay ration by H-64 was of short duration, and she carried a calf only 40 days during her third lactation, while her full-feed record was made at Huntley. The full-feed record of cow 270 was made at Beltsville. Although not entirely comparable, the four records (mature basis) made on the alfalfa hay ration averaged 10,428 pounds of milk and 398 pounds of butterfat, which is 50 and 54 percent, respectively, of the production on full feed.

The 11 records made on the alfalfa hay ration at Woodward (by the 7 cows, W-21, W-44, W-57, W-54, W-55, W-63, and W-69) probably form a better basis of comparison with the Huntley records because the full-feed records were also made at Woodward. These 11 records (table 2) average 10,803 pounds of milk and 353.8 pounds of butterfat, which is considerably less than the cows at Huntley produced on the alfalfa hay ration. The Woodward cows carried calves an average of 177 days while on the alfalfa hay ration, whereas the

Huntley cows carried calves only 135 days. The seven full-feed records of the Woodward cows, on the other hand, when calves were carried for an average of 195 days, averaged 20,286 pounds of milk and 648.5 pounds of butterfat, which is considerably higher in milk than the Huntley cows produced and somewhat higher in butterfat. On the alfalfa hay ration the Woodward cows produced 53.2 percent as much milk and 54.5 percent as much butterfat as they produced on the full-feed ration. As compared to the Huntley ratio of production on alfalfa hay versus full feed this represents a decided decline.

COMPARATIVE PRODUCTION BY MONTHS IN LACTATION

The two systems of feeding have been considered from the standpoint of total production for the lactation period. Table 4 was prepared to show the comparison in average daily milk production by months in lactation for the two systems of feeding. Figure 1 shows the same data graphically. The milk yields shown are the actual yields made by each cow, unless otherwise indicated. The average daily production by months in terms of percentage of the maximum daily production is also shown.

On the alfalfa hay ration the cows reached their highest average daily production during the first month in lactation, produced slightly less during the second month, and declined steadily and rapidly from then on (table 4).

On the full-feed ration the cows did not reach the peak of production until the second month in lactation, from which there was a more gradual decline (table 4). In the twelfth month they were still producing 62.1 percent as much milk as in their highest month. If the age-corrected figures are used instead of actual-yield figures, the rate of decline is much greater. This greater decline may be due to the fact that cows generally are more persistent in their early lactations (the actual records on full feed were for the most part for first lactations) and also that the great body of records from which the age-correction factors were derived were made by cows that were not as persistent producers on an average as the cows in this experiment. In studying figure 1 it will be noted that while the plane of production (age-corrected basis) was much higher after the second month on full feed, the rate of decline on this basis was somewhat similar to that on the alfalfa hay ration.

Since the 15 cows varied considerably in the length of their open or nonpregnant periods while making their records on the two different rations, a comparison was made using only the records of 7 cows that were considered to have comparable open periods on both rations. An open period on one ration (elapsed time between freshening and

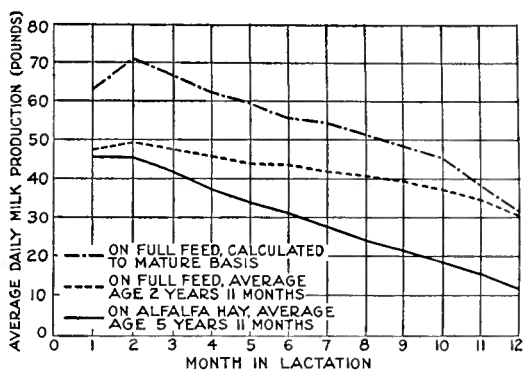


FIGURE 1.—Average daily milk production per cow, by months in lactation, on the alfalfa hay ration and on full feed.

the next conception) was considered comparable with the open period on the other ration if the difference was less than 30 days. For example, if a cow conceived 150 days after freshening on one ration and 170 days after freshening on the other, the difference between the two open periods is less than 30 days and her lactation records are used in the comparison indicated; but if a cow conceived 150 days after freshening on one ration and 200 days after freshening on the other, the difference between the two open periods is more than 30 days, and her records are not used in this comparison. This comparison therefore (table 4) includes 11 records by 7 cows on the alfalfa hay ration that were open for an average of 155 days, and 7 records on full feed when they were open for an average of 162 days. The rate of decline in milk yield by these 7 cows was considerably greater on both rations than the rate of decline by the entire group of 15 cows. The longer period of pregnancy for the 7 cows may have been responsible for this greater rate of decline. The rate of decline by the 7 cows was also relatively greater on the alfalfa hay ration than on the full-feed ration.

TABLE 4.—Average daily milk production by months in lactation, of the 15 cows when fed the alfalfa hay ration (average age 5 years 11 months), and when on full feed (average age 2 years 11 months)

COWS ON ALFALFA HAY RATION												
Cow No.	Average daily milk production by month in lactation											
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	Twelfth
H-31.....pounds..	39.7	42.4	44.9	42.5	38.7	38.3	36.8	31.7	25.9	24.9	24.4	20.0
H-38.....do.....	48.3	47.3	39.1	38.3	35.4	35.3	31.9	29.0	25.8	23.1	21.2	20.7
H-39.....do.....	48.3	47.2	48.7	41.6	39.1	40.2	39.6	38.5	35.0	33.8	33.3	33.4
H-39.....do.....	31.2	41.0	42.0	39.6	36.3	31.6	22.9	21.1	21.3	20.2	18.4	16.3
H-52.....do.....	37.3	46.7	51.3	42.9	41.2	36.2	31.5	30.4	31.0	27.2	22.5	20.3
H-52.....do.....	42.4	48.3	46.6	39.0	33.9	31.1	29.0	26.7	22.0	18.6	13.3	7.7
H-53.....do.....	46.0	56.9	46.4	40.2	39.8	36.6	32.7	29.4	26.4	24.3	12.5	3.2
H-53.....do.....	48.1	50.7	43.6	33.0	27.9	25.8	24.1	23.2	21.7	20.3	15.2	8.6
H-62.....do.....	34.0	36.1	40.2	37.0	29.3	31.8	28.9	22.6	19.3	16.4	15.1	13.0
H-64.....do.....	47.2	47.6	44.9	39.5	36.2	31.0	30.2	23.1	24.9	22.4	15.3	0
W-21.....do.....	47.0	40.1	36.1	33.3	34.7	29.4	22.9	21.7	17.0	18.2	18.1	18.2
W-21.....do.....	64.0	63.0	55.2	53.3	46.8	41.7	32.8	31.3	31.6	28.4	22.2	17.3
W-44.....do.....	51.6	49.1	45.7	44.9	44.7	40.8	36.1	29.2	26.1	20.0	13.0	5.3
W-44.....do.....	45.6	50.7	44.4	41.4	32.2	22.1	14.3	12.4	7.2	0	0	0
W-44.....do.....	40.8	39.1	38.5	34.2	29.9	21.9	19.0	14.9	9.9	6.9	5.4	4.0
W-47.....do.....	49.9	47.4	44.1	37.9	26.2	21.7	15.5	8.2	5.5	3.8	3.8	4.4
W-54.....do.....	45.7	39.3	33.4	30.2	25.2	19.9	17.6	14.4	11.0	8.7	6.2	3.6
W-54.....do.....	45.1	37.5	30.7	26.5	24.7	22.6	22.2	20.7	21.6	20.1	17.1	13.4
W-55.....do.....	50.4	44.3	39.4	29.9	24.6	19.1	18.6	13.1	6.7	2.2	0	0
W-55.....do.....	40.9	39.0	39.3	32.3	20.2	20.9	32.3	32.3	34.1	34.1	33.5	30.0
W-63.....do.....	53.0	47.7	38.8	32.6	30.7	29.3	29.7	25.0	24.1	21.7	20.0	18.7
W-69.....do.....	46.2	44.3	34.4	29.2	29.1	28.8	30.7	27.9	24.3	18.8	11.3	4.3
270.....do.....	52.9	53.7	45.4	40.1	40.9	37.1	35.2	26.4	22.9	14.4	12.8	0
270.....do.....	40.5	32.1	29.2	28.3	31.7	28.9	23.3	22.0	22.4	20.7	20.3	15.0
Average of 24 records pounds..	45.5	45.5	41.8	37.0	33.7	30.5	27.4	24.0	21.6	18.7	15.6	11.6
Relation to maximum daily production (24 records)....percent..	100.0	99.8	91.7	81.1	73.9	66.9	60.1	52.6	47.4	41.0	34.2	25.4
Average of 11 records pounds..	45.5	46.1	41.2	36.8	32.3	28.5	24.4	21.1	18.1	15.2	12.0	8.7
Relation to maximum daily production (11 records)....percent..	98.7	100.0	89.4	79.8	70.0	61.8	52.9	45.9	39.3	33.0	26.0	18.9

¹ Includes only the 11 records of cows H-31 (2), H-39, H-52 (2), W-44 (first and second), W-47 (2), W-54, and W-55 (first), that conceived within a period of 30 days of their corresponding breeding records when on full feed.

TABLE 4.—Average daily milk production by months in lactation, of the 15 cows when fed the alfalfa hay ration (average age 5 years 11 months), and when on full feed (average age 2 years 11 months)—Continued

Cow No.	Average daily milk production by month in lactation											
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	Twelfth
H-31.....pounds..	60.0	63.2	58.8	54.1	47.0	40.8	36.0	31.3	28.5	25.3	22.3	17.4
H-38.....do.....	47.0	50.0	42.2	39.4	40.0	40.2	38.1	40.5	39.6	38.4	40.0	39.5
H-39.....do.....	34.3	35.7	36.4	34.7	33.2	32.4	31.9	30.1	30.0	28.7	27.1	26.2
H-52.....do.....	50.6	54.4	50.2	44.8	42.1	42.0	39.9	38.8	36.6	36.8	35.1	33.0
H-53.....do.....	48.8	47.4	45.4	42.4	38.6	36.5	35.5	33.9	34.3	31.8	35.7	27.7
H-62.....do.....	53.2	53.7	55.9	50.8	42.3	42.5	42.3	42.0	43.6	41.0	37.3	36.3
H-64.....do.....	39.6	46.2	42.9	44.2	44.7	45.7	43.4	43.5	42.3	39.0	37.7	36.0
W-21.....do.....	49.0	47.4	50.5	48.5	45.9	44.7	43.2	39.0	40.0	38.7	41.8	40.6
W-44.....do.....	46.4	45.7	40.3	39.7	34.8	34.8	30.6	33.2	34.0	32.4	31.1	28.0
W-47.....do.....	31.9	34.3	31.0	34.5	35.1	35.3	34.3	36.0	33.2	32.0	28.1	24.1
W-54.....do.....	46.6	46.1	46.6	48.0	49.1	50.0	50.9	50.6	49.4	48.7	38.5	28.8
W-55.....do.....	52.0	57.1	57.9	57.1	56.4	52.3	54.5	50.6	45.8	41.4	36.1	31.0
W-63.....do.....	41.6	42.3	39.4	36.9	35.0	34.8	33.7	33.2	31.0	32.1	29.3	25.6
W-69.....do.....	48.0	46.0	49.0	51.0	50.9	52.7	51.0	49.8	47.0	36.9	31.9	21.5
270.....do.....	64.2	69.3	67.0	63.2	61.6	67.8	59.2	57.4	56.7	54.2	50.2	43.5
Average yield (actual basis).....pounds..	47.5	49.3	47.6	46.0	43.8	43.5	41.6	40.7	39.5	37.2	34.8	30.6
Average yield (mature basis).....pounds..	62.8	71.0	66.5	62.1	59.5	55.7	54.1	51.6	48.1	45.1	38.5	31.7
Relation to maximum daily yield (actual basis).....percent..	96.4	100.0	96.6	93.3	88.8	88.2	84.4	82.6	80.1	75.5	70.6	62.1
Relation to maximum daily yield (mature basis).....percent..	87.4	100.0	93.7	87.5	83.8	78.5	76.2	72.7	67.7	63.5	54.2	44.6
Average yield for 7 ¹ / ₂ records (actual basis).....pounds..	45.7	47.1	45.2	44.4	42.0	40.3	39.1	38.0	36.5	34.3	31.3	26.2
Average yield for 7 ¹ / ₂ records (mature basis).....pounds..	60.0	67.7	63.5	59.3	56.8	53.2	51.6	49.3	45.9	43.1	36.8	30.3
Relation to maximum daily yield (actual).....percent..	97.0	100.0	96.0	94.3	89.2	85.6	83.0	80.7	77.5	72.8	66.5	55.6
Relation to maximum daily yield (mature).....percent..	88.6	100.0	93.8	87.6	83.9	78.6	76.2	72.8	67.8	63.7	54.4	44.8

¹ Includes only the 7 records of cows (H-31, H-39, H-53, W-44, W-47, W-54, and W-55) that conceived within a period of 30 days of their corresponding records on alfalfa hay alone.

The lack of persistency in lactation, which is characteristic of the cows on the alfalfa hay ration, is one of the reasons why their total production on that ration is not higher in relation to their production on the full-feed ration. The greater relative decline on the alfalfa hay ration as the lactation advances may be indicated in another way; that is, the relative yield on the two rations may be compared by months in lactation. Comparing the records made by the seven cows that had comparable open periods on both rations (table 4) the milk yield on the alfalfa hay ration was 75.8 percent of the yield on full feed during the first month of lactation, 68.1 percent the second month, 64.9 the third, 62.1 the fourth, 56.8 the fifth, 53.6 the sixth, 47.3 the seventh, 42.8 the eighth, 39.4 the ninth, 35.2 the tenth, 32.6 the eleventh, and 28.7 percent the twelfth month.

The hypothesis advanced for this more rapid decline in production on the alfalfa hay ration is: (1) These cows were more advanced in age when they made their records on the alfalfa hay ration than when

they made their records on the full-feed ration (for the most part in their first lactation period) and it is to be expected that they would be somewhat less persistent for that reason; (2) these were high-producing cows, and while they were able to consume enough nutrients when on the full-feed ration to produce up to somewhere near their inherent capacity they were unable to consume enough of the more bulky alfalfa hay ration to meet the requirements for maximum production. Consequently the level of production declined to meet the amount of nutrients consumed. During the first 3 months the alfalfa-fed cows were drawing on body reserves to some extent to meet the demands for production. The cows never reached as high a level of production on the alfalfa hay ration as on the full-feed ration, but why the decline should have been more rapid after reaching the point where the consumption of nutrients was more than meeting the demand of production is difficult to determine.

In an attempt to throw further light on the greater rapidity of decline in milk yield on the alfalfa hay ration, compilations were made in which the variable length of pregnancy period, rate and rapidity of decline in milk yield, and rate and decline in amount of hay consumed were brought together in table 5. The data in the first part of the table are for the cows that had comparable pregnancy periods on both rations; the data in the second part of the table are for the cows that were open throughout most of the lactation period on the alfalfa hay ration. In this table the average daily milk yield and the percentage that it represents of the highest average yield during that lactation period, is shown for the third, sixth, ninth, and twelfth months of lactation. For comparison the average daily consumption of hay and the percentage of maximum daily consumption is shown for those same months; and also the average daily yield and the percentage of maximum yield for the same cows when on the full-feed ration. Data for 4 months only are given in order to reduce the number of figures to be compared.

If the cows that conceived within 4 to 6 months after starting a lactation on such a bulky ration as alfalfa hay had had their consumption of hay greatly reduced, owing to the development of the fetus, it might account for the rapid decline in yield. The cows listed in table 5, that were pregnant approximately 7 months of the lactation period, did have a greater decline in hay consumption than the cows that were open throughout most of the lactation period on alfalfa hay, but the difference in hay consumption was not nearly so great as the difference in milk yield. The pregnant cows consumed an average of 35.7 pounds of hay per day during the twelfth month and produced an average of 9.5 pounds of milk per day, while the open cows consumed an average of 40.5 pounds of hay and produced an average of 20.5 pounds of milk.

There were exceptions to the general trend, however. Four of the five open cows were producing in the twelfth month from 27 to 40 percent as much as their maximum production in any month, and were consuming from 74.4 to 87.7 percent as much as their maximum consumption of hay. The fifth cow was producing in the twelfth month 68.6 percent as much as her maximum yield and consuming 93.2 percent as much as her maximum consumption. Three of the pregnant cows were more persistent in yield than four of the open cows, and a fourth cow was in the same range.

TABLE 5.—Comparison of the average daily milk yield on the alfalfa hay ration and on the full-feed ration, and the percentage of maximum yield, for the third, sixth, ninth, and twelfth months of lactation, and the average daily hay consumption and percentage of maximum consumption for the same periods, for the seven cows having comparable pregnancy periods under the two systems of feeding, and for the five cows that were open throughout most of the lactation period on the alfalfa hay ration

SEVEN COWS

Cow No.	Ration	Days conceived after freshening	Milk yield or hay consumption per day	Third month		Sixth month		Ninth month		Twelfth month	
				Average daily quantity	Percentage of maximum	Average daily quantity	Percentage of maximum	Average daily quantity	Percentage of maximum	Average daily quantity	Percentage of maximum
		No.		Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.
H-31	{ Alfalfa	117	{ Milk	44.9	100.0	32.3	85.3	25.9	57.6	20.0	44.5
	{ Hay		{ Hay	40.5	80.5	50.5	100.0	39.4	78.0	45.5	90.1
	{ do	154	{ Milk	39.1	80.0	35.3	72.2	25.8	52.7	20.7	42.3
	{ Full feed	141	{ Hay	46.3	91.8	49.0	97.2	45.8	90.9	38.7	76.7
H-39	{ Alfalfa	196	{ Milk	58.8	93.0	40.8	64.5	28.5	45.1	17.4	27.5
	{ Hay		{ Hay	42.0	100.0	31.6	75.2	21.3	50.7	16.3	40.0
	{ Full feed	170	{ Milk	38.3	82.7	46.3	100.0	31.0	66.9	28.0	60.4
	{ Hay	179	{ Hay	36.4	100.0	32.4	89.0	30.0	82.1	26.2	72.0
H-53	{ Alfalfa	168	{ Milk	46.4	81.5	36.6	69.3	26.4	46.4	3.2	5.6
	{ Hay		{ Hay	43.7	78.6	49.5	89.0	48.1	86.5	41.6	74.8
	{ do	174	{ Milk	43.6	86.0	25.8	50.9	21.7	42.8	8.6	16.9
	{ Full feed	174	{ Hay	45.4	91.9	44.8	90.7	47.3	95.1	40.9	82.8
W-44	{ Alfalfa	159	{ Milk	45.4	82.6	36.5	74.8	34.3	70.3	27.7	56.7
	{ Hay		{ Hay	43.7	88.5	40.8	79.1	26.1	50.6	5.3	10.2
	{ Full feed	177	{ Milk	43.4	80.8	50.7	94.4	48.8	90.8	37.7	70.2
	{ Hay	139	{ Hay	40.3	86.9	34.8	75.0	34.0	73.3	28.0	60.3
W-47	{ Alfalfa	120	{ Milk	44.1	88.4	21.7	43.5	5.5	11.0	4.4	8.9
	{ Hay		{ Hay	45.2	92.6	42.9	87.9	27.0	55.3	28.5	58.4
	{ Full feed	150	{ Milk	33.4	73.1	19.9	43.5	11.0	24.1	3.6	7.8
	{ Hay	160	{ Hay	31.5	100.0	31.5	100.0	29.8	94.6	29.5	93.6
W-54	{ Alfalfa	160	{ Milk	30.7	86.1	35.3	98.1	33.2	92.9	24.1	66.9
	{ Hay		{ Hay	30.7	71.2	22.6	52.4	21.6	50.1	13.4	31.1
	{ Full feed	164	{ Milk	33.3	79.6	36.5	87.3	41.8	100.0	36.9	87.4
	{ Hay	146	{ Hay	46.6	91.5	50.0	98.2	49.4	97.0	28.8	56.6
W-55	{ Alfalfa	146	{ Milk	39.4	78.1	19.1	37.9	6.7	13.3	0	0
	{ Hay		{ Hay	43.7	96.9	44.4	98.4	34.2	75.8	30.0	66.5
	{ Full feed	160	{ Milk	57.9	100.0	52.3	90.3	45.8	79.0	31.0	53.6

FIVE COWS

H-38	{ Alfalfa	(¹)	{ Milk	48.7	100.0	40.2	82.5	35.0	71.8	33.4	68.6
	{ Hay		{ Hay	35.6	68.9	46.0	91.1	49.0	94.9	48.1	93.2
	{ Full feed	228	{ Milk	42.2	84.4	40.2	80.4	39.6	79.2	39.5	79.0
	{ Hay		{ Hay	51.3	100.0	36.2	70.6	31.0	60.4	20.3	39.9
H-52	{ Alfalfa	(¹)	{ Milk	39.6	78.4	46.2	91.5	49.1	97.2	42.0	83.2
	{ Hay		{ Hay	50.2	92.3	42.0	77.2	36.6	65.4	33.0	60.7
	{ Full feed	179	{ Milk	40.2	100.0	31.8	79.1	19.3	48.0	13.0	32.3
	{ Hay		{ Hay	32.1	79.9	40.2	100.0	35.3	87.8	33.7	83.8
H-62	{ Alfalfa	(¹)	{ Milk	55.9	100.0	42.5	76.0	43.6	78.0	36.3	64.9
	{ Hay		{ Hay	55.2	86.2	41.7	65.1	31.6	49.3	17.3	27.0
	{ Full feed	251	{ Milk	54.1	98.2	50.2	91.1	45.9	83.3	41.0	74.0
	{ Hay		{ Hay	50.5	100.0	44.4	87.9	40.0	79.9	40.6	80.4
W-21	{ Alfalfa	(¹)	{ Milk	38.8	73.2	29.3	55.3	24.1	45.5	18.7	35.3
	{ Hay		{ Hay	34.5	80.2	38.7	90.0	36.7	85.4	37.7	87.7
	{ Full feed	166	{ Milk	39.4	93.1	34.8	82.2	31.0	73.3	25.6	60.5
	{ Hay		{ Hay								

¹ Did not conceive during the lactation period on the alfalfa hay ration.

Cow H-31, with two consecutive lactations on the alfalfa hay ration, conceived 117 days after starting on the first lactation. In the twelfth month of the lactation, or the eighth month of pregnancy, she was still producing at the rate of 44.5 percent of her maximum yield of milk and consuming 90.1 percent as much hay as in the month of maximum consumption. Her second lactation period was similar to the first, though on a somewhat lower plane of production. She was more persistent on the alfalfa hay ration than she had been on full feed. The other two cows were H-39, producing 40 percent as much

milk in the twelfth month as in her maximum month's yield and consuming 60.4 percent as much hay; and cow W-54, producing 31.1 percent of her maximum yield and consuming 87.4 percent of her maximum consumption in the twelfth month. The latter cow did not reach as high a level of production as the other cows, at any time in her lactation.

Some of the other cows, including H-53, W-44, W-47, and W-55, that showed a great lack of persistency on the alfalfa hay ration, had been very persistent producers on the full-feed ration. The cows tested at the Woodward station were the most noticeable in this respect. Possibly this was due to the fact that they were not accustomed to rations consisting entirely of roughage. The cows raised at the Huntley station were fed from the age of 8 or 9 months to the time of first freshening, on rations consisting entirely of roughage, and, therefore, were probably more accustomed to such a diet.

FEED AND NUTRIENT CONSUMPTION

The consumption of alfalfa hay, digestible crude protein, and total digestible nutrients by the cows when fed the alfalfa hay ration, and their nutrient requirements according to the Savage feeding standard, are shown in table 6. The amounts of various feeds consumed exclusive of pasture, together with nutrients consumed and required, by the same cows under full-feed conditions are also shown. An average of the first monthly body weight after calving and the body weight nearest the date of record completion, was used in calculating the yearly nutrient requirements for maintenance.

HAY CONSUMPTION

The average amount of hay consumed during a lactation period when the cows were fed the alfalfa hay ration was 14,352 pounds or a little more than 7 tons per cow. The highest individual hay consumption was 17,199 pounds (more than 8½ tons), by cow H-53 during her second lactation. The lowest consumption was 11,085 pounds for cow W-47 during her second lactation.

The cows produced an average of 1 pound of milk for each 1.3 pounds of hay consumed and 1 pound of butterfat for each 38 pounds of hay consumed. This ratio of milk production to alfalfa hay consumption is higher than was reported in the experiments by the Kansas (19), California (1, 20), Nevada (12), and Oregon (18) stations. The ratio of butterfat production to alfalfa consumption is also higher than that reported by these stations, with the exception of California where the cows consumed only 36 pounds of alfalfa hay (or equivalent) for each pound of butterfat produced. The ratios of milk and butterfat produced to alfalfa hay consumed for the stations named and for this experiment are shown in table 7. The 15 cows used in this experiment may have had an inheritance for higher levels of production than the cows used in the other experiments, and they were also milked three times a day as compared with twice a day for the others.

TABLE 6.—Comparative feed and nutrient consumption and nutrient requirements of cows by lactation periods when fed the alfalfa hay ration and when on full feed

Cow No.	When fed the alfalfa hay ration						
	Alfalfa hay consumed	Digestible crude protein consumed	Digestible crude protein required	Excess of digestible crude protein	Total digestible nutrients consumed	Total digestible nutrients required	Excess (+) or deficiency (−) of total digestible nutrients
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
H-31.....	16,134	1,801	1,102	699	8,240	7,930	+310
H-38.....	16,304	1,820	1,071	749	8,327	7,765	+562
H-39 ¹	15,795	1,763	1,211	552	8,067	8,424	−357
H-39 ²	12,857	1,436	993	443	6,594	7,245	−651
H-52 ¹	11,490	1,283	766	517	5,893	5,772	+121
H-52 ¹	15,861	1,770	1,142	628	8,100	8,124	−24
H-52.....	14,984	1,672	1,060	612	7,652	7,835	−183
H-53.....	16,367	1,827	1,191	636	8,359	8,642	−283
H-53.....	17,199	1,919	1,052	867	8,784	7,803	+981
H-62.....	11,954	1,334	899	435	6,105	6,499	−394
H-64 ³	11,794	1,363	917	446	6,014	6,509	−495
H-64 ⁴	11,530	1,333	696	637	5,879	5,162	+717
H-64.....	11,826	1,366	967	399	6,030	7,079	−1,049
W-21.....	17,092	1,937	1,224	713	8,919	8,285	+634
W-44.....	16,278	1,844	1,004	840	8,494	7,139	+1,355
W-44 ⁵	12,155	1,377	688	689	6,343	4,936	+1,407
W-44.....	14,237	1,613	814	799	7,429	6,297	+1,132
W-47.....	13,533	1,533	800	733	7,062	5,927	+1,135
W-47.....	11,085	1,256	859	397	5,784	6,755	−971
W-54.....	13,164	1,492	875	617	6,869	6,441	+428
W-55.....	13,094	1,484	744	740	6,833	5,408	+1,425
W-55.....	16,466	1,866	1,054	812	8,592	7,289	+1,303
W-63.....	13,638	1,545	999	546	7,116	7,214	−98
W-69.....	13,386	1,517	904	613	6,985	6,522	+463
270.....	14,089	1,629	1,065	564	7,184	7,788	−604
270.....	15,158	1,752	996	756	7,729	7,572	+157
Average.....	14,352	1,622	985	637	7,400	7,143	+257

Cow No.	When on full feed							
	Feed consumed					Total digestible nutrients in feeds other than pasture	Total digestible nutrients required	Excess (+) or deficiency (−) of total digestible nutrients (exclusive of pasture)
	Hay	Grain	Silage	Beets or carrots	Pasture			
	Pounds	Pounds	Pounds	Pounds	Days	Pounds	Pounds	Pounds
H-31.....	7,723	4,551	8,647	395	111	8,907	9,510	−603
H-38.....	5,536	3,639	11,881	480	66	7,701	8,412	−711
H-39 ¹	4,573	3,014	9,530	1,135	67	6,424	7,423	−999
H-52 ¹	5,363	3,693	9,785	1,060	104	7,361	8,533	−1,172
H-53.....	6,100	3,449	9,634	950	109	7,520	8,396	−876
H-62.....	3,753	3,790	8,328	1,725	64	6,425	8,112	−1,687
H-64 ²	6,627	5,096	12,926	30	0	9,480	8,327	+1,153
H-64 ³	3,574	3,127	5,960	-----	183	(⁶)	(⁶)	-----
W-21.....	2,980	3,790	9,269	-----	89	5,916	6,953	−1,037
W-44.....	3,979	3,499	6,127	-----	124	6,299	7,186	−887
W-54.....	5,585	4,846	7,458	-----	84	6,832	8,113	−1,281
W-55.....	6,010	5,290	9,675	-----	55	7,685	8,610	−925
W-63.....	6,417	3,683	8,200	-----	35	6,773	7,540	−767
W-69.....	6,535	4,877	7,722	-----	35	7,391	7,990	−599
270.....	7,442	6,316	8,128	2,864 ⁷	0	12,123	11,710	+413
Average.....	5,480	4,177	8,887	1,080	75	7,631	8,344	−713

¹ Milked twice a day when on the alfalfa hay ration, and 3 times a day on full feed.² Bred too soon, record for 285 days; not used in averages.³ Bred too soon, record for 308 days on the alfalfa hay ration.⁴ Bred too soon, record for 265 days; not used in averages.⁵ Includes some estimated sorghum roughage.⁶ Body weights not available.⁷ Includes some Sudan-grass hay.⁸ Record for 285 days; cow went dry.⁹ Dried beet pulp.

TABLE 7.—*Ratio of alfalfa hay consumed to milk and butterfat production by cows fed alfalfa hay only at several experiment stations*

Station	Records	Hay consumed for each pound of milk produced	Hay consumed for each pound of butterfat produced	Station	Records	Hay consumed for each pound of milk produced	Hay consumed for each pound of butterfat produced
	Number	Pounds	Pounds		Number	Pounds	Pounds
Kansas.....	12	2.2	62	Oregon.....	6	2.5	67
California.....	6	1.7	36	This experiment.....	24	1.3	38
Nevada.....	16	1.6	44	Average.....		1.9	49

The amount of hay consumed daily by the 15 cows in this experiment increased on an average until the sixth month in lactation, when a slight but fairly steady decline was noted (table 8). The daily consumption averaged slightly more, however, at the end of the lactation than at the beginning. Some of the cows consumed over 50 pounds of alfalfa hay per day for several months. The greatest amount consumed in 1 day was 69 pounds by cow H-64 at the Mandan station.

TABLE 8.—*Average daily consumption of alfalfa hay by 15 cows during 24 lactation periods, for each month in lactation*

Cow No.	Average daily consumption by month in lactation											
	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th
	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>
H-31.....	34.8	32.9	40.5	46.6	47.7	50.5	50.1	47.8	39.4	45.2	46.7	45.5
H-38.....	43.3	41.9	46.3	46.7	47.0	49.0	50.4	47.2	45.8	40.0	39.8	38.7
H-39.....	25.8	32.2	35.6	39.8	44.2	46.0	47.2	48.9	49.0	51.6	46.5	46.1
H-52.....	27.9	34.1	38.3	40.8	44.2	46.3	39.1	38.5	31.0	27.4	26.9	28.0
H-53.....	23.1	38.9	39.6	42.0	45.8	46.2	48.4	50.5	49.1	48.0	40.3	42.0
H-52.....	35.6	38.4	40.1	42.3	43.4	41.8	40.5	43.0	40.4	43.1	42.0	42.1
H-53.....	39.4	44.9	43.7	46.9	47.8	49.5	50.2	55.6	48.1	49.8	41.6	41.6
H-52.....	38.7	49.4	45.4	46.8	46.5	44.8	46.5	46.4	47.3	45.0	43.8	40.9
H-63.....	22.5	28.1	32.1	36.6	36.7	40.2	39.0	26.0	35.3	34.3	33.7	33.7
H-64.....	30.2	36.7	44.5	45.0	41.2	39.4	38.4	30.3	39.4	34.8	36.0	35.0
H-64.....	31.9	35.3	37.4	38.9	44.5	28.3	30.3	24.4	28.7	30.3	29.0	33.8
W-21.....	46.7	46.8	54.1	55.1	53.2	50.2	48.9	49.6	45.9	39.7	39.1	41.0
W-44.....	41.0	42.2	43.4	53.7	53.7	50.7	48.6	47.3	48.8	45.0	34.6	37.7
W-44.....	35.7	41.7	44.8	47.6	44.0	43.8	45.2	42.9	39.1	34.1	28.2	26.8
W-44.....	34.5	37.3	40.8	38.3	41.0	41.2	40.8	40.5	38.2	38.8	39.0	37.1
W-47.....	44.7	48.8	45.2	42.4	40.7	42.9	36.7	25.6	27.0	27.7	28.9	28.5
W-54.....	31.7	28.3	31.5	31.4	31.6	31.5	29.5	29.7	29.8	29.7	30.0	29.5
W-55.....	34.3	35.4	33.3	33.9	34.5	36.5	37.3	38.7	41.8	35.4	36.7	36.9
W-55.....	42.0	45.1	43.7	42.4	43.7	44.4	42.1	39.1	34.2	28.7	27.2	30.0
W-53.....	45.7	46.0	50.1	44.5	45.7	45.1	45.2	43.1	43.4	44.2	44.3	44.0
W-63.....	43.0	33.9	34.5	36.7	37.3	38.7	41.8	35.4	36.7	37.1	37.0	37.7
W-69.....	34.4	33.9	34.5	36.7	37.3	38.7	41.8	35.4	36.7	37.1	37.0	37.7
270.....	35.7	40.9	40.9	44.6	55.4	52.6	51.3	43.2	37.3	25.0	43.5	35.7
270.....	36.3	36.6	46.1	61.9	53.6	48.7	48.5	44.6	41.7	31.2	25.1	33.0
Average.....	35.6	38.7	41.0	43.0	44.2	43.6	43.2	40.6	39.8	37.6	36.5	37.0

The total amount of hay offered and the amount consumed by each cow are shown in table 9. It was the intention to offer the cows about 10 percent in excess of what they would consume. Difficulty was experienced, however, in doing this. For example, cow H-62 at the Huntley station consumed 11,954 pounds of hay, or only 65.4 percent

of the 18,278 pounds offered. On the other hand, cow W-47 (second lactation) at the Woodward station consumed 11,085 pounds of hay, only 869 pounds less than cow H-62, and consumed 93.4 percent of the amount offered. There was also considerable variation with individual cows in their different lactation periods. Cow H-31, for example, at the Huntley station consumed about the same amount of hay for both lactations, although she was offered 21,434 pounds during her first lactation and 18,681 pounds during her second. In the first lactation she consumed 75.3 percent of the amount offered, and in the second 87.3 percent.

TABLE 9.—*Amount of alfalfa hay offered and the amount and percentage consumed by 15 cows in 24 lactation periods*

Cow No.	Alfalfa hay offered	Alfalfa hay consumed	Percentage of hay consumed	Cow No.	Alfalfa hay offered	Alfalfa hay consumed	Percentage of hay consumed
	<i>Pounds</i>	<i>Pounds</i>			<i>Pounds</i>	<i>Pounds</i>	
H-31.....	{ 21,434	16,134	75.3	W-44.....	{ 19,993	16,278	81.4
H-38.....	{ 18,681	16,304	87.3	W-44 ²	{ 13,720	12,155	88.6
H-39 ¹	{ 18,784	15,795	84.1	W-47.....	{ 15,430	14,237	92.3
H-39 ²	{ 17,093	12,857	75.2	W-47.....	{ 17,394	13,533	77.8
H-52 ¹	{ 13,041	11,490	88.1	W-54.....	{ 11,875	11,085	93.4
H-52 ²	{ 18,783	15,861	84.4	W-54.....	{ 14,362	13,164	91.7
H-52.....	{ 16,947	14,964	88.4	W-55.....	{ 14,665	13,094	89.3
H-53.....	{ 18,801	16,367	87.1	W-55.....	{ 17,835	16,466	92.3
H-62.....	{ 19,281	17,199	89.2	W-63.....	{ 14,742	13,638	92.5
H-64 ³	{ 18,278	11,954	65.4	W-69.....	{ 14,477	13,386	92.5
H-64 ⁴	{ 14,580	11,794	80.9	W-69.....	{ 17,105	14,089	82.4
H-64 ⁴	{ 13,574	11,530	84.9	270.....	{ 17,806	15,158	84.8
H-64.....	{ 14,223	11,826	83.1				
W-21.....	{ 20,695	17,092	82.6	Average.....	{ 16,679	14,134	84.7

¹ Milked twice a day.

² Record for 285 days.

³ Record for 308 days.

⁴ Record for 265 days.

The continued feeding of alfalfa hay alone does not significantly affect the amount consumed, as is shown by the average consumption per cow for the second successive lactation on the alfalfa ration by the five cows H-31, H-52, H-53, W-47, and 270, which was only 251 pounds less than in the first lactation (table 10). The hay consumption was maintained although the average milk production was less for the second than for the first lactation. Body weights were about the same.

TABLE 10.—*Comparative consumption of alfalfa hay by cows that were fed the alfalfa hay ration throughout two or more consecutive lactation periods*

Lactation	Hay consumed by cow no. —								
	H-31	H-39	H-52	H-53	H-64	W-44	W-47	W-55	270
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
First.....	16,134	12,857	15,861	16,367	¹ 11,794	16,278	13,533	13,094	14,089
Second.....	16,304	² 11,490	14,984	17,199	³ 11,530	⁴ 12,155	11,085	16,466	15,158
Third.....					11,826	14,237			

¹ Bred too soon, lactation period only 308 days.

² Bred too soon, lactation period only 285 days.

³ Bred too soon, lactation period only 265 days.

⁴ Record for 285 days, dried off.

The records of the two cows (H-64 and W-44) that were fed the alfalfa hay ration continuously for three consecutive lactations are not entirely comparable, but offer further evidence on this point. H-64 consumed approximately the same amount of hay in all three lactations, but her first lactation period was only 308 days, her second was 265 days, and her third was 365 days. The second lactation of cow W-44 is not comparable with her first and third lactations, so far as hay consumption is concerned, because of its short duration, but in her third lactation period she consumed 13 percent less hay than in her first lactation, and produced 32 percent less milk.

While there was considerable variation in consumption, due probably to the characteristics of the individual cows and to the quality of the hay, it is apparent that cows will consume large amounts of alfalfa hay if it is fed exclusively and will continue this heavy consumption over long periods without any depressing effect on their appetites. For limited periods some of the cows on the alfalfa hay ration exhibited a craving for other roughage. This was most pronounced in the case of cow 270 at the Mandan station. This cow was kept in a fenced-off portion of a new pen barn and was stanchioned only at feeding time. Her pen was bedded with wheat straw. At times she consumed sufficient amounts of the straw bedding to affect her alfalfa hay consumption markedly. Occasionally, some of the cows at the other stations would eat small quantities of bedding but the craving was not marked and they did not eat enough to affect the amount of hay consumed. Possibly, for the cows that were light consumers of alfalfa hay the addition of some other kind of hay to the exclusive alfalfa ration might have increased the consumption of roughage, with a consequent favorable effect on production, but with the heavier consumers it does not seem possible that their capacity for such bulky feed would have permitted a very great increase in consumption.

CHEMICAL ANALYSES AND NUTRIENTS IN THE HAY

The composition of the 34 samples of hay taken for analysis at the 4 stations, and the calculated amounts of digestible crude protein and total digestible nutrients averaged by stations, are given in table 11. The digestion coefficients used for calculating the digestible crude protein and the total digestible nutrients in this table and under Consumption of Nutrients are from Henry and Morrison (13).

The average crude protein content of the hay fed at each station was fairly close, but there was great variation in the individual samples. There was likewise considerable variation in the other nutrients, especially crude fiber. The Huntley and Mandan hays had a much higher average phosphorus content and a lower calcium content than the hays from Ardmore and Woodward. The average ratio of phosphorus to calcium is 1 to 6.6 for the Huntley and Mandan samples and 1 to 10.0 for the Ardmore and Woodward samples. The hay fed at Ardmore and Woodward for the most part was produced under dry-land conditions, while most of the hay fed at Mandan and all of that fed at Huntley was grown under irrigation.

TABLE 11.—*Analyses of samples of the alfalfa hay fed as the sole ration, arranged by stations*

Station where fed	Moisture	Crude protein	Fat	Crude fiber	Nitrogen-free extract	Digestible crude protein	Total digestible nutrients	Calcium	Phosphorus	Remarks (year, cutting, etc.)
	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	
Ardmore, S. Dak....	8.3 9.4 8.7 8.2	14.5 19.6 13.4 15.4	2.1 2.2 1.8 1.6	24.9 17.8 34.5 25.8	39.6 38.5 33.0 41.1	----- ----- ----- -----	----- ----- ----- -----	2.00 2.26 1.23 2.10	0.137 .206 .148 .130	1930, first cutting. 1930, second cutting. 1930, third cutting. 1931.
Average.....	8.65	15.73	1.93	25.75	38.05	11.17	51.29	1.90	.155	
Huntley, Mont....	7.8 9.7 7.7 8.1 9.7 7.8 9.4 7.6 8.0 8.6 8.4 8.4 8.3 7.7 7.8 7.5	17.3 13.9 19.3 15.1 14.5 15.1 16.1 12.3 13.4 14.9 14.9 16.2 15.6 16.8 16.1 19.8	1.9 1.1 2.1 1.9 1.1 2.0 1.8 1.2 1.3 1.1 1.5 1.6 1.4 2.0 2.1 1.6	30.7 33.5 24.6 32.4 35.9 30.6 27.0 37.1 34.1 32.1 33.5 32.2 29.7 30.2 32.8 25.1	33.4 33.5 37.2 33.8 29.7 35.9 37.7 33.6 35.2 34.0 35.0 33.5 37.8 34.8 34.1 37.6	----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----	1.05 1.29 1.10 1.32 1.21 1.16 1.32 1.06 1.07 1.12 1.09 1.13 1.36 1.41 1.06 1.69	.240 .145 .248 .156 .224 .187 .189 .153 .175 .175 .199 .181 .152 .149 .178 .193	1929, first cutting. 1929, second cutting. 1929, third cutting. 1930, second cutting. 1930, second cutting. 1930, second cutting. 1930, third cutting. 1931, first cutting. 1931, second cutting. 1931, third cutting. 1932, first cutting. 1932, second cutting. 1932, third cutting. 1933, first cutting. 1933, second cutting. 1933, third cutting.
Average.....	8.28	15.72	1.61	31.34	34.80	11.16	51.07	1.21	.184	
Woodward, Okla....	10.8 5.9 9.5 8.6 7.5 7.6 7.5 7.4	15.7 15.3 17.7 14.5 15.8 15.7 17.1 15.8	2.3 1.5 2.4 2.1 1.8 2.0 2.0 1.8	26.0 36.1 27.8 30.8 30.4 26.6 25.4 30.4	36.9 35.1 33.7 37.0 37.0 38.5 40.3 37.0	----- ----- ----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- ----- ----- -----	1.32 ----- 1.30 1.44 1.40 1.82 1.35 1.00	.151 ----- .210 .139 .148 .117 .191 .142	1928. 1929. 1930, first cutting. 1930, second cutting. 1932, station cut. 1932, station cut. 1933, Garden City, Kans. 1933, Woodward County, Okla.
Average.....	8.10	15.95	1.99	29.19	36.94	11.33	52.18	1.38	.157	
Mandan, N. Dak....	8.2 8.1 8.2 9.2 8.6 7.3	20.7 12.4 14.0 16.7 16.2 17.7	1.8 1.4 1.3 1.7 1.8 1.8	25.0 35.0 36.2 31.7 30.4 30.7	34.9 35.4 31.9 32.5 34.4 35.0	----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- -----	1.51 1.13 1.04 1.28 1.40 1.14	.192 .138 .159 .222 .178 .223	1930, station grown. 1931, Montana grown. 1931, Montana grown. 1932, station grown. 1932, Montana grown. 1932, Montana grown.
Average.....	8.27	16.28	1.63	31.50	34.02	11.56	50.99	1.25	.187	

CONSUMPTION OF NUTRIENTS

All the cows on the alfalfa hay ration consumed more than enough digestible protein, and in 15 of the 26 lactation periods more than enough total digestible nutrients, to meet their requirements for maintenance and for the amount of milk and butterfat produced during the lactation period (table 6). In only two lactation periods was the deficiency of total digestible nutrients as great as 10 percent of the total requirements. This fact is probably not very significant, however, since the production probably dropped to somewhere near the level of nutrients consumed.

These same cows when on the full-feed ration and producing at a higher level probably also consumed sufficient nutrients to meet their requirements. The data in table 6 showing the nutrients consumed on

the full-feed ration are for the entire lactation period, but do not take into account the nutrients supplied by pasture. The amount of nutrients consumed and required by the 15 cows during that part of their lactation period on full feed when they did not have access to pasture is shown in table 12.

TABLE 12.—*Actual production and feed consumption by the 15 cows during the time they were on the full-feed ration without pasture*

Cow No.	Period on full feed without pasture	Production		Feed consumed				Average body weight	Gain or loss in body weight	Total digestible nutrients		
		Milk	Butter-fat	Grain	Hay	Silage	Roots ¹			Consumed	Required	Excess (+) or deficiency (—)
	Days	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
H-31.....	254	11, 149	389	3, 067	5, 744	7, 380	395	1, 470	+123	6, 656	6, 516	+139
H-38.....	229	9, 046	312	2, 228	4, 945	8, 219	480	1, 372	+132	5, 710	5, 375	+335
H-39.....	235	7, 132	273	1, 763	3, 182	6, 960	1, 135	1, 249	+116	4, 331	4, 730	-339
H-52.....	207	7, 786	259	1, 943	4, 235	7, 273	1, 060	1, 206	+190	5, 046	4, 354	+692
H-53.....	217	7, 556	289	1, 850	5, 167	7, 462	950	1, 247	+156	5, 517	4, 690	+827
H-62.....	236	10, 973	366	2, 875	3, 753	6, 910	1, 725	1, 116	+82	5, 501	5, 197	+304
H-64.....	365	15, 215	522	5, 096	6, 627	12, 926	30	1, 248	+264	9, 480	8, 327	+1, 153
W-21.....	176	7, 343	227	1, 659	² 1, 750	5, 860	-----	(3)	-----	-----	-----	-----
W-44.....	260	8, 808	295	2, 660	² 2, 905	8, 419	-----	1, 021	+38	4, 913	4, 851	+62
W-47.....	238	7, 637	231	2, 204	² 2, 946	5, 652	-----	1, 020	+151	4, 117	4, 115	+2
W-54.....	210	10, 286	328	2, 933	² 3, 890	5, 775	-----	1, 035	+89	5, 155	4, 798	+357
W-55.....	284	13, 838	433	4, 009	² 5, 375	9, 315	-----	1, 116	+198	7, 329	6, 566	+763
W-63.....	291	10, 426	364	3, 018	² 5, 527	8, 200	-----	1, 204	+210	6, 499	6, 102	+397
W-69.....	292	13, 730	434	3, 879	² 5, 770	7, 722	-----	1, 063	+213	7, 159	6, 564	+595
270.....	365	21, 763	800. 5	6, 316	7, 442	8, 128	² 2, 864	1, 458	+154	12, 123	11, 710	+413
Average ..	257	10, 846	368. 2	3, 033	4, 617	7, 747	³ 1, 080	1, 202	+151	6, 398	5, 993	+405

¹ Sugar beets or carrots.

² Hay consumption partially estimated. Includes some Sudan grass hay.

³ Body weights not available.

⁴ Beet pulp.

⁵ Average for 8 cows.

These data indicate that all but 1 cow consumed an excess of nutrients over their requirements, and that for the 15 head the digestible nutrients consumed exceeded the requirements by an average of 6.7 percent. On both rations, then, the books were practically balanced at the end of the lactation year insofar as the consumption of total digestible nutrients meeting the needs for maintenance and milk and butterfat production is concerned. Actually, however, there was considerable difference in the way in which the requirements were met on the two rations. Six cows on the full-feed ration did not have access to pasture in the early months of lactation and consumed on an average of 83 percent of their nutrient requirements in the first month of lactation, 93 percent in the second month, and 96 percent in the third month. The 15 cows in 24 lactation periods on the alfalfa hay ration had an average consumption of 74 percent of their nutrient requirements in the first month, 82 percent in the second month, and 91 percent in the third month.

The average daily requirements per cow for each month for maintenance and for milk yield during the 24 lactations on the alfalfa hay ration, and the percentage of the total requirements that was consumed, are shown in table 13.

TABLE 13.—Average daily requirements and average daily consumption per cow of total digestible nutrients, by months in lactation, during 24 lactation periods on the alfalfa hay ration

Month in lactation	Digestible nutrients required for—			Total digestible nutrients consumed ²	Excess (+) or deficiency (—) of total digestible nutrients	Percent-age consumed of requirements
	Maintenance	Production ¹	Total			
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	
First.....	10.168	14.546	24.714	18.291	-6.423	74
Second.....	9.835	14.515	24.350	19.884	-4.466	82
Third.....	9.748	13.334	23.082	21.066	-2.016	91
Fourth.....	9.732	11.803	21.535	22.093	+ .558	102
Fifth.....	9.716	10.750	20.466	22.710	+2.244	111
Sixth.....	9.732	9.750	19.482	22.402	+2.920	115
Seventh.....	9.812	8.741	18.553	22.196	+3.643	120
Eighth.....	9.835	7.656	17.491	20.860	+3.369	119
Ninth.....	9.970	6.890	16.860	20.449	+3.589	121
Tenth.....	10.144	5.975	16.119	19.319	+3.200	120
Eleventh.....	10.318	4.976	15.294	18.754	+3.460	122
Twelfth.....	10.556	3.700	14.256	19.011	+4.745	133

¹ Calculation based on milk testing 3.5 percent of butterfat.² Calculation based on total digestible nutrient content in alfalfa hay of 51.38 percent, the average of samples from all stations.

On the alfalfa hay ration the greatest deficiency in consumption of total digestible nutrients occurred in the months of greatest production. The first month in lactation showed the greatest deficiency and as consumption increased and production decreased, the deficiency became less each month until by the fourth month there was a small average excess in daily consumption. The decline in milk yield (on the average) was not seriously checked when this occurred, however, and since the consumption of alfalfa continued to increase until the fifth month and to hold up well through the sixth and seventh months, then to decline but slowly to the twelfth month, there was an increasingly greater average excess of nutrients consumed over requirements.

Why was the decline in milk yield not checked in the fourth month when the consumption of nutrients was more than enough to meet the needs for the amount of milk and butterfat produced? Was it because these animals had expended too much energy in the consumption of the large amounts of bulky feeds in the first part of the lactation period when heavy production was making a great demand on reserve nutrients, or was there a deficiency of some essential nutrient in the alfalfa hay ration that limited the yield? Some light may be thrown on these questions by comparing the two rations to show the amount of milk produced per pound of digestible nutrients consumed. Since most of these cows made their records on full feed during their first lactation periods and their records on the alfalfa hay ration when most of them were mature, they were larger animals when the latter records were made. Therefore, any comparison should be based on the amount of total digestible nutrients available for production, that is, on the difference between the amount consumed and the amount required for maintenance. The fact that all but 2 of the 15 cows were on pasture varying lengths of time during the lactations in which they were on the full-feed rations makes some of the individual data incomparable. Five cows (H-64, 270, W-55, W-63, and W-69) were selected for comparison.

TABLE 14.—Comparison of the production, and the total digestible nutrients consumed in excess of maintenance requirements, by five cows on the alfalfa hay ration and on the full-feed ration without pasture for comparable lengths of time

Cow No.	Days in lactation compared	Nutrients required for maintenance		Average body weight on—		Milk production		Butterfat production		Nutrients consumed in excess of maintenance requirements when on—		Production on alfalfa hay in relation to production on full feed		Relation of the amount of nutrients consumed, in excess of maintenance requirements, on alfalfa hay to the amount consumed on full feed	
		Full feed	Alfalfa hay	Full feed	Alfalfa hay	Full feed	Alfalfa hay	Full feed	Alfalfa hay	Full feed	Alfalfa hay	Milk	Butterfat		Percent
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Percent	Percent		
H-64	308	2,966	3,163	1,215	1,296	13,212	10,294	445.1	370.9	5,196	2,851	77.9	83.3	54.9	54.9
	265	2,502	2,809	1,191	1,338	11,584	7,108	385.1	290.3	4,536	3,070	61.4	67.6	67.7	67.7
W-55	365	3,609	3,717	1,248	1,285	15,215	9,978	522.0	375.5	5,870	2,313	65.5	71.9	39.4	39.4
	184	1,557	1,559	1,068	1,097	10,307	6,788	320.0	209.7	3,433	2,536	65.9	65.5	73.8	73.8
W-63	234	1,557	1,704	1,068	1,169	10,307	6,796	320.0	200.2	3,433	2,716	65.9	62.6	79.1	79.1
W-69	252	2,094	2,186	1,129	1,179	8,945	8,254	305.0	288.3	3,684	2,400	92.3	94.6	65.1	65.1
	252	1,961	2,243	982	1,124	12,468	8,375	394.7	270.3	4,375	2,572	67.2	68.4	58.8	58.8
	365	4,219	4,388	1,458	1,517	21,763	11,210	800.5	437.5	7,904	2,796	51.5	54.5	35.4	35.4
270	365	4,219	4,171	1,458	1,442	21,763	9,713	800.5	389.4	7,904	3,558	44.6	48.6	45.0	45.0
Average	280	2,743	2,882	1,202	1,272	13,952	8,724	477.0	311.3	5,148	2,757	62.5	65.3	53.6	53.6

Cows H-64 and 270 had no pasture while on the full-feed rations, and cows W-55, W-63, and W-69 were on the full-feed ration 184, 234, and 252 days, respectively, before they had pasture. The amount of digestible nutrients consumed in excess of maintenance requirements, that is, the amount of nutrients available for production, was computed for these cows up to the time they had access to pasture and also for comparable periods on the alfalfa hay ration. The data for the comparison of nine lactation periods for these five cows are shown in table 14.

The comparison shows that the five cows for nine lactations (280 days) on the full-feed ration produced 2.71 pounds of milk containing 3.42 percent butterfat to each pound of total digestible nutrients available for production; and during their nine lactations on the alfalfa hay ration (280 days) they produced 3.16 pounds of milk containing 3.57 percent butterfat to each pound of nutrients available for production. This comparison would appear to indicate that the digestible nutrients in the alfalfa hay were just as efficient, pound for pound, as were the digestible nutrients in the ration that contained a variety of grains, corn silage, and alfalfa hay.

However, the individual results as indicated in table 14 are quite variable. Cow H-64 had yields of milk in her three lactation periods that were 77.9, 61.4, and 65.5 percent as great on alfalfa as on full feed for the same periods of time; whereas, the amount of nutrients available for production was 54.9, 67.7, and 39.4 percent, respectively, as great on alfalfa as on full feed. This is a great variation in relative consumption on the two rations, and does not seem consistent with the relative yields. The percentages for relative yields of cow W-55 in her two lactation periods on alfalfa were lower than the percentages for her relative consumption, while the reverse was true for cows W-63 and W-69. Cow 270 had two 365-day lactation periods on alfalfa hay for comparison with a 365-day lactation period on full feed without pasture. This cow made a very large record on full feed and was well advanced in age when she made the records on alfalfa. Her yield on alfalfa was relatively low and her consumption was also relatively low. The relationship between yield and consumption is closer for this cow in her second lactation on alfalfa than for any other cow.

The data for these five cows show surprisingly little relationship between the ratio of yield on the two rations and the ratio of consumption of total digestible nutrients above the requirements for maintenance. Perhaps this was due to environmental factors that affected the individual animals in different ways, such as the differences in age of the animals when they made the different records, or the fact that all the cows except those raised at the Huntley station were unaccustomed to rations consisting entirely of roughage, which undoubtedly resulted in some cases in a lowered consumption. The ideal method of carrying out such an experiment would be to use only mature cows for making records on both the alfalfa hay and the full-feed rations, and only cows that had been accustomed to rations consisting entirely of roughage. Such animals were not available in sufficient numbers in the station herds. Perhaps if immature grass, or alfalfa hay with less crude fiber and a more concentrated nutrient content than hay cut at the usual stages of maturity, had been fed to these cows in the early

months of the lactation period, they might have been able to consume more digestible nutrients, reach a higher level of production, and have a less rapid decline in milk yield.

CONSUMPTION OF CALCIUM AND PHOSPHORUS

It was not planned to determine the possible mineral deficiencies of a ration composed entirely of alfalfa hay in this experiment, because facilities for balance experiments are not available at the field stations. The data available from this experiment, therefore, do not afford conclusive evidence on this phase of the problem, though they are of interest when considered from the standpoint of results obtained by other investigators.

To offset a probable shortage of phosphorus in an exclusive ration of alfalfa hay and with cows of such high production, special steamed bonemeal was placed in a sheltered box where each cow had continuous or frequent access to it. A weighed amount was placed in the box and at frequent intervals the remaining portion was weighed and the difference was considered as the amount consumed. After the experiment had been in progress a few weeks, it was observed that some of the cows were not taking any bonemeal and some only a small amount. The amount consumed from some of the boxes was so small as to be easily accounted for by a change in moisture content. Cows in the regular milking herds also consumed extremely small amounts. At the Mandan station bonemeal prepared especially for poultry feeding was substituted for the steamed bonemeal with the expectation that consumption might be increased, as was indicated by results at the Beltsville station (21). The change had little effect, however. Measuring the bonemeal consumed by the majority of the cows was later discontinued because it was realized that the methods employed were not sufficiently accurate. However, data were obtained for seven cows for an average of 361 days covering both the lactating and dry periods. These cows consumed an average of 9.26 g of bonemeal per day. Samples of the bonemeal which were chemically analyzed were very uniform and showed an average calcium content of 32.82 percent and a phosphorus content of 13.45 percent.

The amounts of calcium and phosphorus consumed by the 15 cows when fed the alfalfa hay ration during 24 lactations are shown in table 15. The phosphorus requirements of these cows were calculated according to the standard recommended by Huffman and associates (15), that is, 10 g of phosphorus per day per 1,000 pounds body weight and 0.75 g of phosphorus per pound of milk produced. During lactation the cows consumed on an average 11,601 g of phosphorus in the hay and bonemeal, or 91 percent of the 12,720 g required. If only the phosphorus in the alfalfa hay is considered, the cows consumed 88 percent of their phosphorus requirements during lactation. The lowest consumption of phosphorus was for cow W-47 during her second lactation when she consumed only 74 percent of her requirements; the highest was for cow H-53, second lactation, when she exceeded her requirements by 10 percent.

The calcium and phosphorus consumption and the phosphorus requirements per cow per day by months in lactation are shown in table 16. Calcium and phosphorus consumption in the hay is based on the average content in all the hay samples analyzed (table 11). During the first month in lactation the cows consumed only 61 percent

of their phosphorus requirements if in addition to the hay they ate an average of 9.26 g of bonemeal per day, or 58 percent without the bonemeal. The deficiency steadily became less, but it was not until the sixth month in the lactation period that the phosphorus consumption approached the requirements. From then on the consumption exceeded the requirements and by the twelfth month the cows were consuming 35 percent more phosphorus than they required. The average hay consumption continued at approximately 35 pounds daily while the cows were dry, and they were consuming enough phosphorus in hay alone to exceed their maximum body weight requirements by 81 percent. While the shortage of phosphorus was rather pronounced during the first 4 months in lactation, the excess during the last 4 months in lactation and during the dry period would probably offset the shortage incurred during the first few months and the cows should have been able to build up a reserve supply.

TABLE 15.—*Calcium and phosphorus consumption and phosphorus requirements of 15 cows fed the alfalfa hay ration (with free access to bonemeal) for 24 lactations*

Cow No.	Alfalfa hay consumption	Estimated bonemeal consumption ¹	Calcium consumption			Phosphorus consumption			Total phosphorus required	Excess (+) or deficiency (−) of phosphorus	Percentage of required phosphorus consumed
			In hay	In bonemeal	Total	In hay	In bonemeal	Total			
	<i>Pounds</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	
H-31	{ 16, 134	3, 380	88, 543	1, 109	89, 652	13, 471	455	13, 926	14, 254	−328	98
H-38	{ 16, 304	3, 380	89, 495	1, 109	90, 604	13, 608	455	14, 063	13, 875	+188	101
H-38	{ 15, 795	3, 380	86, 683	1, 109	87, 792	13, 200	455	13, 655	15, 760	−2, 105	87
H-39	{ 12, 857	3, 380	110, 814	1, 109	111, 923	9, 027	455	9, 482	12, 491	−3, 009	76
H-52	{ 15, 861	3, 380	87, 046	1, 109	88, 155	13, 245	455	13, 700	14, 426	−726	95
H-52	{ 14, 984	3, 380	82, 238	1, 109	83, 347	12, 519	455	12, 974	13, 509	−535	96
H-53	{ 16, 367	3, 380	89, 813	1, 109	90, 922	13, 653	455	14, 108	14, 621	−513	96
H-62	{ 17, 199	3, 380	94, 394	1, 109	95, 503	14, 334	455	14, 789	13, 414	+1, 375	110
H-62	{ 11, 954	3, 380	65, 591	1, 109	66, 700	9, 879	455	10, 334	11, 760	−1, 326	89
H-64 ²	{ 11, 794	2, 852	66, 861		67, 797	10, 025	384	10, 409	11, 713	−1, 304	89
H-64	{ 11, 826	3, 380	67, 042	1, 109	68, 151	10, 025	455	10, 480	12, 174	−1, 694	86
W-21	{ 17, 092	3, 380	107, 004	1, 109	108, 113	12, 156	455	12, 611	16, 084	−3, 473	78
W-44	{ 16, 278	3, 380	101, 879	1, 109	102, 988	11, 612	455	12, 067	13, 031	−964	93
W-44 ³	{ 12, 155	2, 639	76, 069		76, 935	8, 664	355	9, 019	9, 017	+2	100
W-44	{ 14, 237	3, 380	89, 132	1, 109	90, 241	10, 161	455	10, 616	10, 685	−69	99
W-47	{ 13, 533	3, 380	84, 732	1, 109	85, 841	9, 616	455	10, 071	10, 748	−677	94
W-54	{ 11, 085	3, 380	69, 401	1, 109	70, 510	7, 893	455	8, 348	11, 633	−3, 285	74
W-54	{ 13, 164	3, 380	82, 419	1, 109	83, 528	9, 390	455	9, 845	11, 487	−1, 642	86
W-55	{ 13, 094	3, 380	81, 966	1, 109	83, 075	9, 344	455	9, 799	9, 973	−174	98
W-64	{ 16, 466	3, 380	103, 058	1, 109	104, 167	11, 748	455	12, 203	13, 901	−1, 698	88
W-64	{ 13, 638	3, 380	85, 368	1, 109	86, 477	9, 707	455	10, 162	12, 032	−2, 770	79
W-69	{ 13, 386	3, 380	83, 780	1, 109	84, 889	9, 526	455	9, 981	11, 858	−1, 877	84
270	{ 14, 089	3, 380	79, 879	1, 109	80, 988	11, 930	455	12, 385	13, 384	−999	93
270	{ 15, 158	3, 380	85, 957	1, 109	87, 066	12, 837	453	13, 292	12, 548	+744	106
Average	14, 352	3, 327	85, 799	1, 092	86, 890	11, 153	448	11, 601	12, 720	−1, 119	91

¹ Based on an average daily consumption by 7 cows (p. 30).

² Record for 308 days.

³ Record for 285 days, cow went dry.

Results of investigations on calcium metabolism have been somewhat contradictory. Consequently, the data in tables 15 and 16 are confined to the amounts of calcium consumed. Meigs and coworkers (16) recently suggested that for Jersey cows which are capable of giving 3,000 kg of milk or more annually, an intake of 25 g of calcium daily is somewhat inadequate. As the average daily intake of calcium for the Holstein cows in this experiment in each month of lactation was well over 200 g per day, it is evident that they received sufficient calcium.

TABLE 16.—Average daily calcium and phosphorus consumption and phosphorus requirements by months in lactation of 15 cows fed the alfalfa hay ration for 24 lactations

Month in lactation	Average body weight	Average hay consumption per day	Average milk production per day	Calcium consumed per day			Phosphorus consumed per day			Phosphorus required per day	Excess (+) or deficiency (−) of phosphorus	Percentage of required phosphorus consumed
				In hay	In bonemeal ¹	Total	In hay	In bonemeal	Total			
	Pounds	Pounds	Pounds	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	
First.....	1,283	35.6	45.6	209.61	3.04	212.65	27.47	1.25	28.72	47.03	−18.31	61
Second.....	1,241	38.7	45.5	227.86	3.04	230.90	29.86	1.25	31.11	46.54	−15.43	67
Third.....	1,230	41.1	41.8	241.99	3.04	245.03	31.71	1.25	32.96	43.65	−10.69	76
Fourth.....	1,228	43.0	37.0	253.15	3.04	256.19	33.18	1.25	34.43	40.03	−5.60	86
Fifth.....	1,226	44.2	33.7	260.23	3.04	263.27	34.10	1.25	35.35	37.54	−2.19	94
Sixth.....	1,228	43.6	30.5	256.69	3.04	259.73	33.64	1.25	34.89	35.16	−.27	99
Seventh.....	1,238	43.2	27.4	254.33	3.04	257.37	33.33	1.25	34.58	32.93	+1.65	105
Eighth.....	1,241	40.6	24.0	238.65	3.04	241.69	31.33	1.25	32.58	30.41	+2.17	107
Ninth.....	1,258	39.8	21.6	234.42	3.04	237.46	30.71	1.25	31.96	28.78	+3.18	111
Tenth.....	1,280	37.6	18.7	221.40	3.04	224.44	29.01	1.25	30.26	26.83	+3.43	113
Eleventh.....	1,302	36.5	15.6	214.92	3.04	217.96	28.16	1.25	29.41	24.72	+4.69	119
Twelfth.....	1,332	37.0	11.6	217.86	3.04	220.90	28.55	1.25	29.80	22.02	+7.78	135

¹ Bonemeal consumption estimated (see text).

The calcium-phosphorus ratio of the hay samples analyzed averaged 7.6:1, which is a much higher ratio than is usually considered desirable. The ideal proportion of these minerals is assumed to be between the ratios of 1:1 and 2:1. When an ample supply of vitamin D is present, the proportion of calcium can probably be much greater than 2:1 and still give satisfactory results. Haag, Jones, and Brandt (10) obtained distinctly positive calcium and phosphorus balances with a cow fed on alfalfa hay and bonemeal. There were no outward indications that any of these cows on the alfalfa hay ration suffered from mineral deficiencies. One of the cows at the Woodward station was killed at the end of her lactation period on the alfalfa hay ration and bones from her skeleton were examined and analyzed. They appeared to be normal in every respect.

EFFECTS OF FEEDING ALFALFA HAY ALONE ON CONDITION OF THE COWS AND ON THE MILK

Much information concerning the condition of the cows, such as age, breeding and calving records, body weights, etc., has been given in considering the comparative quantities of milk and butterfat produced on the two rations, and in discussing whether the nutrients and minerals consumed on the hay ration were meeting the animals' requirements for maintenance and production.

Additional information obtained in this experiment from observations of the effects of feeding alfalfa hay alone over long periods, on the condition of the cows in respect to gain or loss in body weight, fertility, breeding and calving, percentage of fat in the milk, and abnormal milk is presented in this part of the bulletin. The observations and conclusions of other investigators were previously mentioned in reviewing the literature.

GAIN OR LOSS IN BODY WEIGHT

One of the chief points of interest with respect to the feeding of a ration restricted to alfalfa hay for extended periods is the effect on body weight. It was recognized that a comparison of the monthly

body weights during the lactation periods on the alfalfa ration with corresponding body weights under other systems of feeding would not necessarily give a correct interpretation, since it would not show the ability of the alfalfa-fed animals to recover any loss in weight sustained during the dry period. Comparisons based on precalving weights before going on alfalfa and precalving weights following lactation on alfalfa, together with the monthly weights while on alfalfa, probably offer the fairest means of comparison.

Table 17 was prepared to show these data for the cows during their first and second lactations. All the cows had been fed grain (either full-feed or limited-grain rations) during the lactation period preceding their first lactation on the alfalfa hay ration. The average precalving weight following the grain feeding, and just prior to the lactation on alfalfa, of the 11 cows that are comparable was 1,505 pounds. The average precalving body weight of the same cows following one lactation on alfalfa was 1,483 pounds, an average loss of 22 pounds per cow on this method of comparison. However, 5

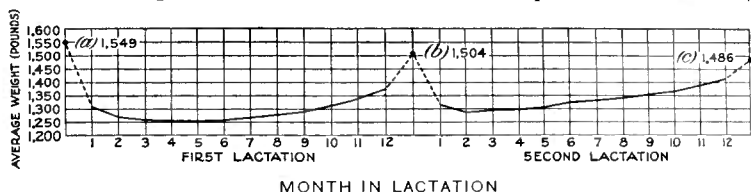


FIGURE 2.—Average monthly body weights of eight cows that were on the alfalfa hay ration for two consecutive lactation periods; and precalving weights (a) following the previous ration, (b) following the first and (c) the second lactation on alfalfa.

cows, of which 4 were at the Woodward station, gained weight and 6 cows lost weight, the maximum loss being 154 pounds for cow 270.

It is probably more significant to compare the weights of eight of the nine cows that were on the alfalfa hay ration for two consecutive lactations. The ninth cow, W-47, is not included because she aborted during the eleventh month of her first lactation and was dry for approximately 17 months before she started her second lactation. The precalving weights of the eight cows previous to their first lactation on the alfalfa hay ration averaged 1,549 pounds, and their precalving weights following their first lactation averaged 1,504 pounds, or a loss of 45 pounds per cow. Their average precalving weight following their second lactation on alfalfa was 18 pounds less than their precalving weight following their first lactation. For their two lactations on alfalfa they showed an average combined loss of 63 pounds, based on precalving weights.

In the first lactation period there was a decided drop in weight from the first to the second month and a continued small loss until the fifth month, after which the eight cows gained gradually and steadily. Their continuous weight curve for the two lactations is shown in figure 2.

It is interesting to note the marked difference in the weight curve for their second lactation period. Although they averaged 45 pounds less previous to calving than for their preceding lactation period, their first calving weight (first month in lactation) was slightly more than that of the first month of the first lactation period. They started to gain in weight beginning with the fifth month in lactation and continued to gain steadily. For their twelfth month in lactation they averaged 1,411 pounds, which was 34 pounds more than they weighed at the corresponding month during their first lactation.

TABLE 17.—*Precalving and monthly weights and gain or loss in weight of cows fed the alfalfa hay ration for one and two consecutive lactation periods*

Cow No.	Pre-calving weight (A)	Average weight during months of first lactation period										Twelfth month	Eleventh month	Tenth month	Ninth month	Eighth month	Seventh month	Sixth month	Fifth month	Fourth month	Third month	Second month	First month	Pre-calving weight following lactation period (B)	Differences in pre-calving weights	
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
H-31	F 1,642	1,329	1,263	1,260	1,256	1,252	1,208	1,331	1,360	1,384	1,403	1,427	1,503	1,533	1,539	1,518	1,497	1,467	1,435	1,403	1,380	1,350	1,329	1,303	1,503	-139
H-38	L 1,606	1,422	1,326	1,265	1,206	1,235	1,263	1,292	1,271	1,290	1,295	1,292	1,290	1,282	1,271	1,262	1,263	1,258	1,247	1,238	1,230	1,210	1,190	1,169	1,148	1,127
H-39	L 1,364	1,270	1,305	1,340	1,351	1,338	1,313	1,273	1,247	1,239	1,235	1,232	1,230	1,228	1,227	1,226	1,225	1,224	1,223	1,222	1,221	1,220	1,219	1,218	1,217	1,216
H-52	L 1,683	1,340	1,260	1,282	1,303	1,301	1,324	1,344	1,367	1,380	1,399	1,418	1,437	1,456	1,475	1,494	1,513	1,532	1,551	1,570	1,589	1,608	1,627	1,646	1,665	1,684
H-53	L 1,651	1,321	1,353	1,377	1,392	1,396	1,370	1,344	1,318	1,292	1,266	1,240	1,214	1,188	1,162	1,136	1,110	1,084	1,058	1,032	1,006	980	954	928	902	876
H-62	F 1,403	1,246	1,244	1,218	1,223	1,248	1,275	1,296	1,310	1,317	1,345	1,360	1,380	1,390	1,405	1,420	1,435	1,450	1,465	1,480	1,495	1,510	1,525	1,540	1,555	1,570
H-64	L 1,432	1,246	1,244	1,218	1,223	1,248	1,275	1,296	1,310	1,317	1,345	1,360	1,380	1,390	1,405	1,420	1,435	1,450	1,465	1,480	1,495	1,510	1,525	1,540	1,555	1,570
W-21	F 1,385	1,189	1,096	1,063	1,043	1,033	1,051	1,047	1,027	1,065	1,091	1,128	1,165	1,202	1,239	1,276	1,313	1,350	1,387	1,424	1,461	1,498	1,535	1,572	1,609	1,646
W-47	L 1,310	1,117	1,086	1,094	1,116	1,134	1,149	1,168	1,183	1,197	1,212	1,227	1,242	1,257	1,272	1,287	1,302	1,317	1,332	1,347	1,362	1,377	1,392	1,407	1,422	1,437
W-54	L 1,300	1,117	1,105	1,110	1,126	1,149	1,174	1,199	1,224	1,249	1,274	1,299	1,324	1,349	1,374	1,399	1,424	1,449	1,474	1,499	1,524	1,549	1,574	1,599	1,624	1,649
W-55	F 1,310	1,118	1,105	1,110	1,126	1,149	1,174	1,199	1,224	1,249	1,274	1,299	1,324	1,349	1,374	1,399	1,424	1,449	1,474	1,499	1,524	1,549	1,574	1,599	1,624	1,649
W-63	F 1,570	1,245	1,291	1,338	1,385	1,432	1,479	1,526	1,573	1,620	1,667	1,714	1,761	1,808	1,855	1,902	1,949	1,996	2,043	2,090	2,137	2,184	2,231	2,278	2,325	2,372
W-69	F 1,200	1,190	1,083	1,068	1,086	1,048	1,049	1,057	1,072	1,109	1,163	1,223	1,283	1,343	1,403	1,463	1,523	1,583	1,643	1,703	1,763	1,823	1,883	1,943	2,003	2,063
270	L 1,737	1,229	1,229	1,226	1,218	1,219	1,225	1,229	1,242	1,264	1,294	1,336	1,377	1,418	1,459	1,500	1,541	1,582	1,623	1,664	1,705	1,746	1,787	1,828	1,869	1,910
Average of 11 ⁶	1,505	1,272	1,229	1,226	1,218	1,219	1,225	1,229	1,242	1,264	1,294	1,336	1,377	1,418	1,459	1,500	1,541	1,582	1,623	1,664	1,705	1,746	1,787	1,828	1,869	1,910
Average of 8 ⁷	1,949	1,305	1,266	1,257	1,252	1,257	1,269	1,278	1,290	1,311	1,339	1,377	1,415	1,453	1,491	1,529	1,567	1,605	1,643	1,681	1,719	1,757	1,795	1,833	1,871	1,909

TABLE 17.—*Precalving and monthly weights and gain or loss in weight of cows fed the alfalfa hay ration for one and two consecutive lactation periods—Continued*

Cow No.	Precalving weight	Average weight during months of second lactation period												Pre-calving weight following two consecutive lactation periods (C)	Difference in pre-calving weights between—		
		First month	Second month	Third month	Fourth month	Fifth month	Sixth month	Seventh month	Eighth month	Ninth month	Tenth month	Eleventh month	Twelfth month		B minus C	A minus C	
H-31	Pounds	1,325	1,305	1,364	1,374	1,373	1,389	1,387	1,407	1,414	1,401	1,416	1,439	Pounds	1,468	Pounds	-174
H-38	do															-35	
H-39	do	1,338	1,299	1,309	1,331	1,342	1,355	1,360	1,362	1,383	1,402	1,451	1,466	1,407	1,513	-111	-157
H-52	do	1,459	1,404	1,381	1,371	1,373	1,360	1,338	1,335	1,380	1,423	1,451	1,466	1,513	1,617	-94	-170
H-53	do	1,383	1,359	1,396	1,399	1,429	1,479	1,483	1,473	1,473	1,469	1,487	1,508	1,617		-108	-64
H-62	do																
H-64	do	1,273	1,267	1,249	1,245	1,262	1,297	1,345	1,379	1,397	1,403	1,453	1,474	1,495	1,495	+115	+2
W-21	do																
W-44	do	1,139	1,111	1,094	1,089	1,075	1,078	1,100	1,105	1,116	1,166	1,228	1,280	1,400	1,488	+115	
W-47	do	1,414	1,346	1,275	1,246	1,251	1,260	1,265	1,285	1,329	1,384	1,425	1,448	1,512	1,512	-170	+202
W-54	do																
W-55	do	1,159	1,143	1,144	1,151	1,155	1,169	1,179	1,211	1,241	1,234	1,244	1,268	1,407	1,407	+82	+187
W-63	do																
W-69	do	1,411	1,415	1,420	1,389	1,413	1,452	1,463	1,456	1,443	1,447	1,443	1,444	1,494	1,494	-89	-243
270	do																
Average of 87	do	1,311	1,288	1,295	1,294	1,303	1,322	1,332	1,341	1,356	1,368	1,389	1,411	1,486	1,486	-18	-63

1 On (F) full-grain or (L) limited-grain system of feeding.

2 Not with calf.

3 Milked for 308 days, calved in 11 months.

4 Not reliable.

5 Not reliable.

6 Includes cows H-31, H-39, H-52, H-64, W-44, W-47, W-54, W-55, W-69, and 270.

7 Includes cows H-31, H-39, H-52, H-64, W-44, W-55, and 270.

8 Milked for 285 days, calved in 10 months.

9 Milked for 265 days, calved in 11 months.

The previous system of feeding may have had some effect on the body weights during the first lactation on the alfalfa hay ration. Four cows, H-31, W-44, W-55, and W-69, had been on full feed before they were started on the alfalfa hay ration. They lost an

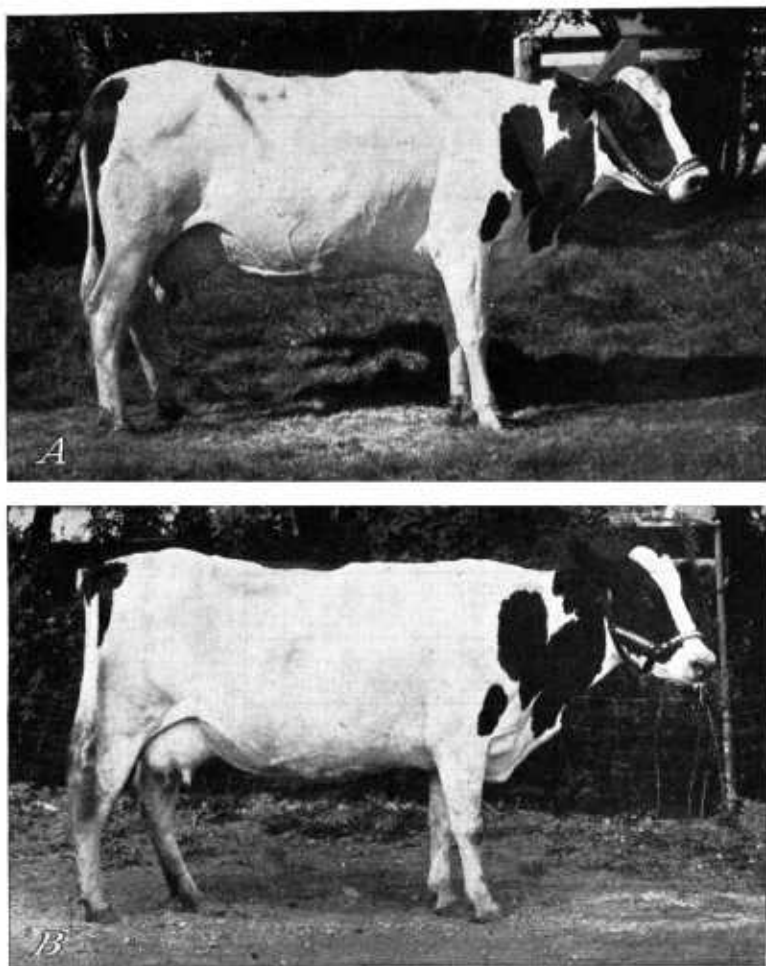


FIGURE 3.—Condition of cow H-31 at different times during lactation on the alfalfa hay ration: *A*, after 214 days in milk (first lactation; *B*, after 136 days in milk (second lactation).

average of 14.2 pounds during the first lactations on the alfalfa hay ration. Three of these four cows started the lactation as 3-year-olds. They carried calves for an average of 233.5 days during the lactation period and produced 353.3 pounds of butterfat (actual production). Six cows, H-39, H-52, H-53, H-64, W-54, and 270, had been fed under limited-grain conditions before they were started on the alfalfa hay ration. Their average loss in body weight was 48.5 pounds

during the first lactation on the alfalfa hay ration. They carried calves for an average of 179 days and produced 415.3 pounds of butterfat (actual production). Four of these cows were mature when they started the lactation period and two were 4-year-olds. Differences in age, production, and length of time a calf was carried, may

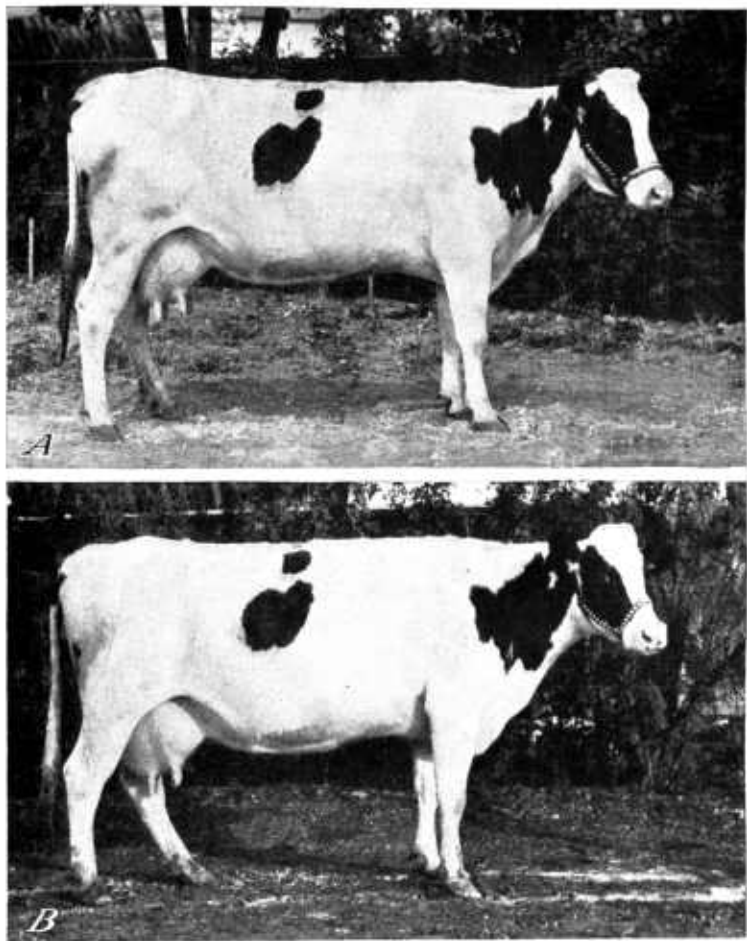


FIGURE 4.—Condition of cow H-53 at different times during lactation on the alfalfa hay ration: A, After 184 days in milk (first lactation); B, after 143 days in milk (second lactation).

have been factors in causing the difference in loss of weight in the two groups, as well as method of feeding in the prior lactation period.

The data indicate there is a slight decline in body weight during the first lactation on an exclusive ration of alfalfa hay, which is somewhat more pronounced when the lactation follows one on limited grain than when it follows heavy feeding of grain. There does not appear to be any significant decline in body weight for the second

consecutive lactation on alfalfa. Data for the third consecutive lactation are very limited, but they show no evidence of a further decline in weight. The experiments by Headley (12), previously reviewed, corroborate this interpretation.

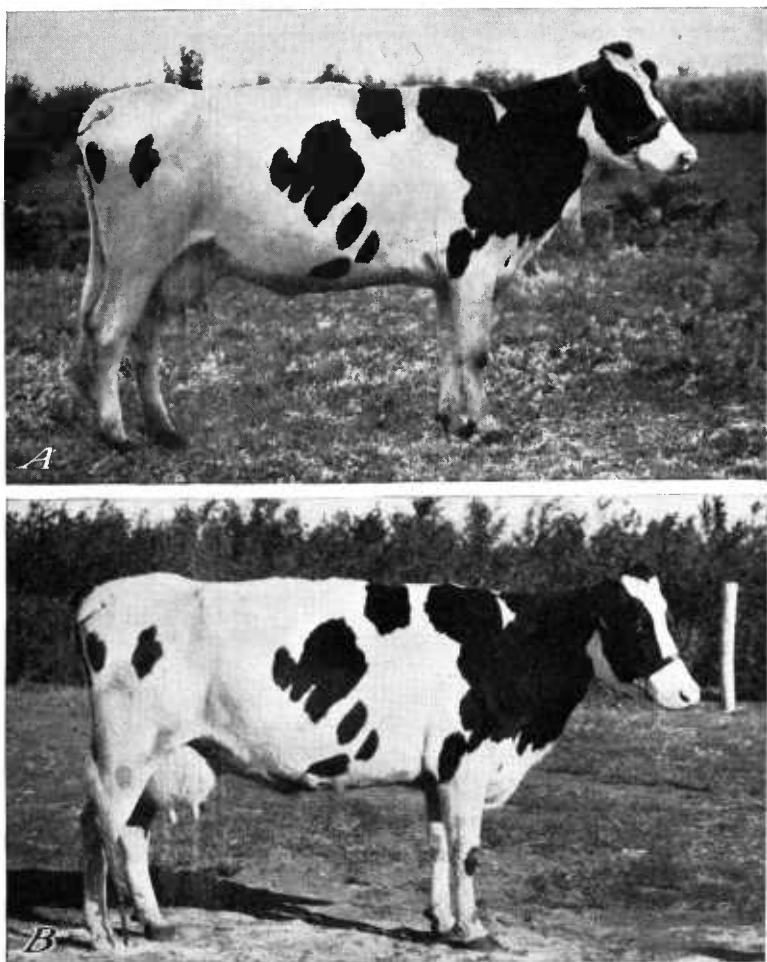


FIGURE 5.—Condition of cow H-34 at different times during lactation on the alfalfa hay ration: A, After 97 days in milk (first lactation); B, after 193 days in milk (third lactation).

While the cows fed alfalfa hay alone were lighter in weight than when they were fed grain in addition, at no time could they be called extremely thin or emaciated. Early in their lactations they became thin, but at the end of their lactations and during their dry periods they took on weight and had the appearance of well-fed cows. The photographs of cows H-31, H-53, and H-64 are included as being typical of their condition (figs. 3-5).

EFFECT ON FERTILITY AND ON BREEDING AND CALVING

During the progress of this experiment numerous questions have been asked as to the effect of an exclusive ration of alfalfa hay, especially when fed over long periods, on the fertility and other breeding conditions of the cows. These questions have arisen probably because the feed was restricted to one plant and because a shortage of phosphorus was possible. A review of the literature does not reveal any data that would suggest lack of fertility or breeding troubles in cows when fed exclusively on alfalfa hay. In the Kansas experiments (19) less difficulty was experienced in bringing about conception in cows fed alfalfa hay than in those fed mixed rations. The data from the Nevada experiment (12) are limited and inconclusive from this standpoint, and only a suggestion of breeding trouble with cows fed alfalfa hay was mentioned.

One of the best measures of fertility in cows, if the bull is known to be fertile, is the number of services necessary for conception. Table 18 was prepared to show the number and ratio of services per conception (1) when the cows were fed alfalfa hay as the sole ration, (2) when the same cows were on full-feed rations, and (3) when the cows were fed on all planes of feeding except a sole ration of alfalfa hay. The latter grouping includes those cows fed full-grain rations, limited-grain rations, and roughage-alone rations. In most cases, pasture was a part of the ration.

TABLE 18.—*Effect of feeding an exclusive ration of alfalfa hay as compared with other systems of feeding on ratio of services to conceptions*

Cow No.	When fed alfalfa hay as the sole ration						When on full feed		When on all systems not including hay alone	
	First lactation		Second lactation		Third lactation		Serv-ices	Concep-tions	Serv-ices	Concep-tions
	Serv-ices	Concep-tions	Serv-ices	Concep-tions	Serv-ices	Concep-tions				
	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
H-31.....	1	1	1	1			2	2	7	7
H-38 ¹	0	0					4	2	8	4
H-39.....	2	1	1	1			4	2	14	6
H-52.....	5	1	2	1			1	1	9	5
H-53.....	2	1	1	1			1	1	5	5
H-62 ²	0	0					2	1	3	2
H-64.....	1	1	1	1	4	1	1	1	4	3
W-21 ⁴	0	0					1	1	10	6
W-44.....	1	1	1	1	1	1	2	1	4	3
W-47.....	1	1	2	1	1	1	1	1	3	3
W-54.....	1	1					2	1	5	3
W-55.....	1	1	2	1			1	1	2	2
W-63.....	2	1					1	1	5	2
W-69.....	1	1					1	1	3	3
270.....	1	1	2	1			5	2	18	7
Total.....	19	12	13	9	6	3	22	15	79	49
Ratio.....	1.58:1		1.44:1		2.00:1		1.47:1		1.61:1	

¹ H-38 did not come in oestrus during her lactation on alfalfa hay. Data not included in totals or ratios.

² H-62 developed vaginitis; did not conceive. Data not included in totals or ratios.

³ Bull used was of questionable fertility.

⁴ W-21 was in oestrus at all times; did not conceive. Data not included.

If H-52, the only cow that gave any great trouble in conceiving during the first lactation, is excluded, the ratio is 1.27 services per conception instead of 1.58. It will be noted also that cow H-64 was bred four times before she conceived during her third lactation. The bull to which she was bred was of uncertain fertility and undoubtedly was responsible for her failure to conceive. Her breeding record for other lactations is almost perfect. Apparently the continuous feeding of alfalfa for as many as three lactations had no effect on the fertility of the cows as indicated by the ratio of services to conceptions. Considering all the lactations on the alfalfa hay ration together, the ratio is 1.58 services per conception. Omitting the data for H-52 during her first lactation on the alfalfa hay ration and for H-64 in her third lactation on alfalfa, there were 22 conceptions resulting from 29 services during all lactations on the alfalfa hay ration, a ratio of 1.32 services per conception.

The breeding records of cows H-38, H-62, and W-21 are given but are not included in the calculations. Cow H-38 did not come in oestrus during her lactation on the alfalfa hay ration and was not bred. An epidemic of vaginitis started in the Huntley herd during the time this experiment was running and approximately half of the cows showed irregular oestral periods and other symptoms of the disease. The uterus of cow H-38 was enlarged and flabby, although her ovaries were pronounced normal. After completing her record on alfalfa hay, she was given a limited-grain ration and pasture with the regular herd. She came in oestrus 7 months after completing her record on alfalfa hay and was bred but did not conceive. She came in oestrus again in 78 days, was bred and conceived. As so many other cows in the herd fed limited- and full-grain rations were similarly affected, it is believed that the exclusive feeding of alfalfa hay was not responsible for the abnormal breeding condition of cow H-38. Cow H-62 was also in the Huntley herd and developed vaginitis at the same time. Cow W-21 developed the typical symptoms of a nymphomaniac early in her lactation on alfalfa. Near the end of the lactation she became stiff in the rear quarters and walked with difficulty. She was later sold as a nonbreeder. The ration of alfalfa hay was not considered responsible for her condition.

Under full-feed conditions the same cows required 1.47 services per conception. Under all systems of feeding, except the alfalfa hay ration, the same cows required 1.61 services per conception, which is essentially the same ratio as when they were fed the alfalfa hay ration. Some of the sires used were quite old and at times showed evidence of low fertility which would influence these data. This was the case under all systems of feeding, however. The data clearly show that the exclusive feeding of alfalfa hay over long periods had no detrimental effect on the fertility of cows as measured by the ratio of services to conception. That the exclusive feeding of alfalfa hay was not harmful from the standpoint of normal calves dropped is evidenced by the fact that of the 23 conceptions resulting in births, 20 of the calves, or 87 percent, were normal and living at birth. One calf was dead at birth and there were two abortions. Of 48 conceptions resulting in births on all other systems of feeding, the same cows dropped 43 living normal calves or 90 percent. Two of the calves were dead at birth and there were three abortions.

SEX RATIO OF THE CALVES

The total number of calves of each sex that were born following the lactation periods on the alfalfa hay ration and following the lactation period on the full-feed ration was determined in order to learn whether either type of ration had any effect on the sex ratio. There were 24 calves born following lactations on the alfalfa hay ration, of which 14 or 58 percent were females. There were 16 calves dropped following lactations on the full-feed ration of which 11 or 69 percent were males. The number of calves is probably too small for the results to be significant, but they are so interesting that further data on the subject will be secured. This study of the sex ratio is prompted by the observation of Gerstell (8) that the fawn crop produced on an overbrowsed portion of the Pennsylvania deer range showed a sex ratio wherein the females outnumbered the males by more than 2 to 1, while on the less heavily browsed portions of the range, the ratio never equalled or exceeded a 2 to 1 ratio in favor of the females.

It has been shown previously that the cows on the alfalfa hay ration in this experiment were actually underfed only during the first 3 months of the lactation period. Presumably any factor that would affect the sex ratio would have to be active at the time of conception. At the time of conception most of the alfalfa-fed cows were receiving sufficient nutrients to meet their requirements, though a short time previously they had been somewhat underfed.

INFLUENCE OF EXCLUSIVE RATION OF ALFALFA HAY ON PERCENTAGE OF FAT IN THE MILK

There was an increase in the average percentage of fat in the milk when the cows were on the alfalfa hay ration. The average percentage of fat in the milk of each cow for each of the 26 records made on alfalfa hay and also for the 15 records made on full feed is given in table 19. In 18 of the 26 lactations (70 percent) on alfalfa the percentage of fat in the milk was higher than when the same cows were on full feed. It is probable that the increase in percentage of fat is the result of the reduced level of milk production when on the alfalfa hay ration. The average percentage of fat in the milk was higher when on the alfalfa hay ration in spite of the fact that the cows were practically mature, whereas their average age was 2 years 11 months when they were on the full-feed ration. It is a well-established fact that as age advances the percentage of fat in the milk tends to decline slightly.

The cows that had two or more consecutive lactations on the alfalfa hay ration showed a slight tendency toward an increased percentage of fat in the milk produced during the second and third lactations. Of the nine cows that had two consecutive lactations on the alfalfa hay ration, five showed a higher percentage of fat during their second lactation. This increase, however, was always accompanied by, and was probably the result of, a lowered level of milk production for the later lactation.

One Holstein cow fed exclusively on alfalfa hay by Woll (1) at the California station for two consecutive lactations showed an increase in percentage of fat in her second as compared with her first lactation. Her total milk production was slightly less for the second lactation. In the Kansas experiment (19) there was a decrease in the percentage

of fat for the second consecutive lactation on hay alone as compared with the first, which in this case was accompanied by a slight increase in the amount of milk produced. In the Nevada experiment (12) there was a gradual decline in percentage of fat from the first to the third consecutive lactation and a gradual increase in total milk produced by lactations. For the group of cows that received grain in alternate years the average milk production and percentage of fat was slightly lower than during the 2 years when only alfalfa hay was fed.

TABLE 19.—Comparative effect of the alfalfa hay ration and the full-feed ration on the average percentage of butterfat in the milk

Cow No.	Average butterfat test of milk when on—		Cow no.	Average butterfat test of milk when on—		Cow no.	Average butterfat test of milk when on—	
	Alfalfa hay alone	Full feed		Alfalfa hay alone	Full feed		Alfalfa hay alone	Full feed
	Percent	Percent		Percent	Percent		Percent	Percent
H-31-----	{3.49}	3.35	H-64-----	{3.60}	3.43	W-55-----	{3.11}	3.14
H-38-----	{3.51}	3.33		{3.66}		W-63-----	{3.06}	3.49
H-39-----	{3.38}	3.81	W-21-----	{3.77}	3.12	W-69-----	3.45	3.13
	{3.75}			3.23		270-----	3.29	3.89
H-52-----	{3.98}	3.45	W-44-----	{3.47}	3.44		{3.90}	
	{3.73}			{3.32}			{4.01}	
	{3.70}		W-47-----	{3.54}	3.41	Average--	3.53	3.42
H-53-----	{4.13}	3.75		{3.08}				
	{3.70}		W-54-----	{3.11}	3.21			
H-62-----	3.36	3.36		3.36				

While the data in this experiment are not extensive enough to show that the exclusive feeding of alfalfa hay over long periods will in itself definitely increase the percentage of fat in milk, they do indicate there is no decrease.

ABNORMAL FLAVORS AND ODORS IN THE MILK

The milk of cow H-39 at the Ardmore station developed a very strong odor and taste shortly after she calved for her second lactation on the alfalfa hay ration, and the condition persisted for practically the entire lactation. If the same abnormality was present during her first lactation on alfalfa, it was so slight that it was not observed.

The milk of cow H-52 at the Huntley station developed a very distinct odor of sulphur and tar immediately after she calved for her first lactation on the alfalfa hay ration. Her calving was abnormal and she was given daily vaginal douches over a period of 30 days. The odor in the milk cleared up in 3 weeks, however, and was probably due to her condition following abnormal calving rather than to the alfalfa hay ration. It will be recalled that this cow required five services for conception during this lactation which is further evidence of an abnormal physical condition. These were the only cases of abnormal milk noted. No attempt was made, however, to detect alfalfa flavors or odors in the milk during the experiment.

ECONOMIC PHASE OF EXCLUSIVE FEEDING OF ALFALFA HAY

The economic phase of feeding dairy cattle on rations restricted to alfalfa hay is of great importance.

Data from this experiment and from other feeding experiments carried on at the Bureau's field stations have been used by Graves

and Shepherd⁶ as a basis for a study of certain phases of the economics of dairy cattle feeding. They analyzed the published information showing the cost of producing various crops in eight counties in three Midwestern States and found that alfalfa hay produced a greater quantity of total digestible nutrients per acre than any other crop, or 18 percent more than corn, which ranked second. The cost of producing 100 pounds of total digestible nutrients was the same in alfalfa hay and timothy hay and these hays produced the nutrients at less cost than any other crop, with clover hay a close second. Compared with the cost in alfalfa or timothy hay, the cost was 34 percent greater in husked corn, 154 percent greater in corn silage, 155 percent greater in oats, 189 percent greater in wheat, and 111 percent greater in barley.

Using these cost figures and the acre yields on which they were based, Graves and Shepherd calculated the cost of growing the feeds consumed by cows in feeding experiments at the Bureau's various stations, when the cows were fed the following rations: (1) Roughage alone; (2) roughage at will and 1 pound of grain to each 3 pounds of milk produced (full-grain ration); and (3) roughage at will and 1 pound of grain to each 6 pounds of milk produced (limited-grain ration).

When the relative production of milk and butterfat on the three rations was compared, and the cost of producing the feed and the value of the product were also taken into consideration, the results were such that the investigators concluded that many farmers would find it advantageous to change their system of farming to one in which they would keep most of their land in permanent pastures and in legumes and grow very little grain. The pastures and other roughage would be the basal ration and grain would be fed only when the resulting increase in milk or butterfat production could be obtained at a profit, based on the cost of producing home-grown grain or on the price of purchased grain. When the prices for milk or butterfat were low in relation to grain prices the dairy farmer would feed roughage more exclusively. Production would be lower when less grain was included in the ration, but the cost of the ration would also be enough lower to make production more profitable.

SUMMARY AND CONCLUSIONS

This study was undertaken primarily to determine the advantages or disadvantages of feeding dairy cows on a ration consisting entirely of alfalfa hay, as compared to other systems of feeding, with particular reference to the relative production of milk and butterfat and to the effects of the alfalfa hay ration on the fertility, breeding, and calving activity, and general condition of the cows.

Feeding experiments were conducted over a period of several years at four of the Bureau's field experiment stations, in which 15 Holstein-Friesian cows were fed for a total of 26 lactation periods on the alfalfa hay ration, for comparative study with 15 lactation records made previously by the same cows under full-feed conditions. The latter records were made in connection with the regular test required of all cows in the Bureau's breeding experiments.

The cows fed the alfalfa hay ration had access to bonemeal and the full-feed ration consisted of roughage and grain fed at the rate of 1 pound to each 3 pounds of milk produced, and pasture in most cases.

⁶ Graves, R. R., and Shepherd, J. B. See footnote 4.

On the alfalfa hay ration, the 15 cows averaged 11,125 pounds of milk and 389.6 pounds of butterfat (mature basis) for 24 lactation periods. This was 57 percent as much milk and 60 percent as much butterfat as they averaged under full-feed conditions. There is evidence, however, to indicate that cows accustomed to a ration consisting entirely of high-quality roughage for long periods may exceed these percentages somewhat.

Seven cows that were fed the alfalfa hay ration for two consecutive lactation periods averaged 10 percent less in butterfat production in the second lactation than in the first. The difference for individual cows ranged from a 40-percent decrease to a 40-percent increase in the second lactation, although only one cow made an increase. The higher average production in the first lactation may have been due in part to the higher condition of the cows resulting from grain feeding in preceding lactations.

The decline in daily milk yield throughout the lactation period was more rapid when the cows were on the alfalfa hay ration than when they were under full-feed conditions. During the sixth month in lactation, the average daily milk production was 61.8 percent of the maximum daily production on the alfalfa hay ration, compared with 85.6 percent of the maximum on full feed.

The cows in this experiment consumed an average of 14,352 pounds, or slightly more than 7 tons, of alfalfa hay per cow for each lactation period. One cow consumed more than 8½ tons. The cows reached their highest average daily consumption of 44.2 pounds during their fifth month in lactation. The highest individual daily consumption was 69 pounds.

They consumed an average of 1.3 pounds of alfalfa hay for each pound of milk produced and 38 pounds of alfalfa hay for each pound of butterfat produced.

Feeding alfalfa hay continuously over two lactation periods had little effect on consumption. This is shown by the fact that five cows fed hay alone under comparable conditions consumed an average of only 251 pounds less hay in the second lactation than in the first.

Under the conditions of this experiment the cows refused to eat approximately 15 percent of the amount of hay offered to them, but there was great variation in this respect, due probably to differences in the palatability of the hay fed and individuality of the cows.

There was marked variation in the nutrients and minerals in the various lots of hay fed, even in that produced on the same land and during the same year.

On the alfalfa hay ration, the 15 cows consumed an average of 3.6 percent more total digestible nutrients per lactation than they required for maintenance and production. They consumed only 74, 82, and 91 percent of their requirements in the first, second, and third month of the lactation, respectively. From the fourth to the twelfth month there was an increase each successive month in the nutrients consumed in excess of requirements.

Six of these cows that did not have pasture early in the lactation period when they were on the full-feed ration, consumed on the average 83, 93, and 96 percent of their nutrient requirements in the first, second, and third month of the lactation, respectively.

A comparison of nine records under both systems of feeding for the first 280 days of lactation (the average number of days the nine cows

were on the full-feed ration without pasture) shows that on the alfalfa hay ration the cows produced 62.5 percent as much milk and consumed 53.6 percent as much total digestible nutrients above maintenance requirements as when they were on the full-feed ration. There was great variation in the ratio of production and the ratio of consumption of nutrients for the nine records, however. On alfalfa hay alone they gave an average of 3.16 pounds of (3.57-percent fat) milk for each pound of total digestible nutrients available for production, as compared with an average of 2.71 pounds of (3.49-percent fat) milk for each pound of total digestible nutrients consumed above maintenance requirements when on full feed. Apparently there was little difference in efficiency for milk production of the total digestible nutrients derived from the alfalfa and that derived from the grain, hay, and silage ration.

The cows on the alfalfa hay ration consumed but little of the special steamed bonemeal that was made available to them. The amount they did consume was insignificant from the standpoint of the calcium and phosphorus furnished.

From the standpoint of phosphorus consumed, it is believed that the cows did not suffer a shortage as measured by the standard used. While there was a deficiency up to and including their sixth month in lactation, the excess for the remainder of their lactations and dry periods would probably more than offset any deficiency incurred during the first 6 months in lactation. The data, however, do not show how much of the phosphorus was utilized.

Only two cows in this experiment showed any marked craving for other roughage or feed. However, other cows in the station herds that were fed on a variety of feeds showed similar symptoms. None of the symptoms that are commonly associated with depraved appetite, or lack of appetite were observed.

The decline in body weight for the first year on the alfalfa hay ration, as shown by the precalving weight prior to the first lactation period and the precalving weight subsequent to the first lactation, average for 11 cows, was 22 pounds, or 1.4 percent. After the first lactation there was no further measurable decline in body weight when all influencing factors are considered.

While the cows were lighter in body weight when fed on hay only, they had a well-fed appearance.

The long-continued feeding of the alfalfa hay ration had no detrimental effect on the fertility or breeding and calving condition of the cows.

The exclusive feeding of alfalfa hay over long periods did not lower the percentage of butterfat in the milk. There is evidence that the percentage of butterfat was increased somewhat though this increase was probably associated with level of milk production.

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